Arnold Schwarzenegger
Governor

DEVELOPING RECOMMENDATIONS TO INTEGRATE EMERGING TECHNOLOGIES INTO THE 2008 NONRESIDENTIAL STANDARDS

PIER FINAL PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

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October 2008
CEC-500-2008-070

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Acknowledgments

The amount of work that has led up to this report is immense, with material drawn from 16 different Public Interest Energy Research (PIER) technical reports. Numerous researchers and PIER contract managers were involved in the development of these technical reports, and no doubt the number of names would be in the hundreds. The authors would like to acknowledge all the researchers who developed the various ideas and concepts that lead up to this report, and thank them for their contributions of ideas for energy conservation strategies. In addition, the authors would like to thank the following individuals who provided specific input and ideas to the changes developed in this report.

Donald Aumann	California Lighting Technology Center
Fred Bauman	Center for the Built Environment
Tom Webster	Center for the Built Environment

Please cite this report as follows:

Dodd, M.C., 2006. *Development of Recommendations to Integrate Emerging Technologies into the 2008 Nonresidential Standards.* EnergySoft, LLC for the California Energy Commission, PIER Building End-Use Energy Efficiency Program. CEC-500-2006-070.

Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Development of Recommendations to Integrate Emerging Technologies Into the 2008 Nonresidential Standards is the final report for the Development of Recommendations to Integrate Emerging Technologies into the 2008 Nonresidential Standards project (contract number 500-05-003), conducted by EnergySoft, LLC. The information from this project contributes to PIER's Building End-Use Energy Efficiency program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-654-4878.

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Abstract

Over the past several years, the California Energy Commission's Public Interest Energy Research program has conducted a series of research projects using outside contractors to investigate newer energy savings strategies. This report evaluates the work of these contractors to identify energy efficient measures and technologies for nonresidential buildings that might be suitable to incorporate into the 2008 California Energy Efficiency Standards for Residential and Nonresidential Buildings, Title 24, Part 6 of the California Code of Regulations. This work is part of a larger effort to develop the 2008 Title 24 Standards, initiated by the California Energy Commission.

After completing the evaluation, the author finalized measure information templates for 11 measures recommended for incorporation into the standards. The measure information templates—required by Buildings and Appliances Office for code change considerations—were presented at a public workshop on February 22, 2006. This report presents the results of the evaluation and discusses issues related to the Measure Information Templates. The final section of this report includes recommended changes and corrections to Chapter 5 of the *Nonresidential Alternative Calculation Method Manual*, which explains the requirements for approval of alternative calculation methods used to demonstrate compliance with the Energy Efficiency Standards for nonresidential buildings.

Keywords: 2008 California Energy Efficiency Standards for Residential and Nonresidential Buildings, 2008 Title 24 Standards, nonresidential buildings, energy efficiency, Nonresidential Alternative Calculation Method Manual, ACM Manual, Measure Information Template

Executive Summary

Overview

In October 2005, the staff of the Buildings and Appliances Office of the California Energy Commission (Energy Commission) held the first in a series of public meetings to solicit input from interested parties on developing the 2008 California Energy Efficiency Standards for Residential and Nonresidential Buildings (Standards), Title 24, Part 6, of the California Code of Regulations. A standardized measure template—required for each measure being considered for incorporation into the standards—was provided for outside parties to use when proposing changes to the code.

The Buildings and Appliances Office staff was the potential value of the many research projects conducted by outside contractors for the Energy Commission's Public Interest Energy Research (PIER) Buildings End-Use Energy Efficiency Program investigating newer energy savings strategies. Many reports on these projects by the contractors identify possible energy savings measures.

EnergySoft evaluated the PIER Buildings Research, Development, and Demonstration report portfolio for their potential to provide information on energy efficient measures suitable to incorporate into the nonresidential portion of the 2008 Standards. A parallel effort (conducted by others) has been initiated to evaluate residential measures.

EnergySoft conducted the following technical tasks:

- Task 2: Evaluate PIER Buildings Research and Development report portfolio.
- Task 3: Develop standards and *Alternative Calculation Method (ACM) Manual* change proposals for PIER research and development products.
- Task 4: Provide support to Energy Commission staff to develop alternative calculation method reference test files for 2005 Standards

Task 2 Activities

Under Task 2, EnergySoft conducted a preliminary screening of all relevant PIER research products including a thorough review of 17 PIER research and development reports, on lighting and mechanical measures. However, no envelope or domestic hot water technologies were evaluated as part of this work.

This process determined several categories of potential changes to the 2008 Nonresidential Standards or to the *Nonresidential Alternative Calculation Method Manual* (ACM Manual) and screened out several projects which either had no applicability to, or were not good candidates for, change proposals. The categories of potential changes are as follows:

- Performance: Recommend implementing the technology as a credit under the performance compliance approach, requiring changes in the Nonresidential ACM Manual.

- Mandatory Measures: Recommend changes in the mandatory measures sections of the standards.
- Prescriptive: Recommend changes in the prescriptive sections of the standards.
- Testing: Recommend changes related to functional testing requirements as found in the Acceptance Requirements in the standards.

Table ES1 presents the PIER reports that have been evaluated, and the related recommended changes developed under Task 3. As shown, 11 of the 17 technologies evaluated were deemed good candidates for incorporation into the 2008 Standards.

Table ES1: Task 2 Evaluation Results

Technology Evaluated	Recommended Standard/ACM Change
FDD for Rooftop Air Conditioners	Performance
FDD for Air Handling Units & VAV Boxes	Performance
LED Exterior Lighting	Prescriptive
Retrofit Fluorescent Dimming	None
Load Shedding Ballast	Prescriptive
Classroom Photosensor	None
Hotel Bathroom Lighting	Mandatory Measures
Downlight Systems	None
Integrated Classroom Lighting	Prescriptive
Bi-Level Stairwell Fixtures	Prescriptive
HID Electronic Ballasts	None
Prioritized R&D Standards Connections	All
Performance Monitoring Specifications	Performance/Testing
Large Commercial Buildings Distribution Systems	None
Displacement Ventilation	Performance
Natural Ventilation	Performance
Underfloor Air Distribution Systems	Performance

Task 3 Activities

The Building and Appliance Office requires a completed measure information template for each measure being considered for incorporation into the standards. Under Task 3, EnergySoft developed specific change proposals as measure information templates for each 11 PIER technologies recommended for the standards after the Task 2 evaluation. To complete the templates, EnergySoft considered information from the related PIER reports, as well as feedback from Building and Appliance Office staff and from researchers. The finished measure information templates were presented at the 2008 Standards Public Workshop on February 22, 2006.

The proposed changes to the standards were considered by Building and Appliance Office staff to include in the 2008 language. Standards language will then be developed based on input received at the workshops.

Task 4 Activities

The ACM Manual explains the requirements for approval of alternative calculation methods used to demonstrate compliance with the Energy Efficiency Standards for nonresidential buildings. Since the development of the original Alternative Calculation Method manual 15 years ago, many newer and more sophisticated building energy analysis tools have been developed, including EnergyPlus, which incorporates many newer features funded under the PIER Program. Under Task 4, EnergySoft performed a comprehensive review of the existing Nonresidential Alternative Calculation Method test process and developed detailed recommendations to update the ACM test files and manual to modeling standards that can better accommodate current and future best practices.

This review included a thorough assessment of Chapter 5 of the Alternative Calculation Method Manual, which covers the certification tests required for new compliance software applying for certification, and the revised certification files developed by Lawrence Berkeley National Laboratory (LBNL) as part of its work related to EnergyPlus to provide feedback. EnergySoft used assessment results to advise the Building and Appliance Office staff on issues and test problems that would limit using EnergyPlus and other newer generation software tools. This document provides specific recommendations for changes to Chapter 5 that facilitate using these newer software tools.

Conclusions

Of the 17 PIER projects screened, 11 showed sufficient merit to warrant developing measure information templates. During the February 2006 workshop, a formal presentation was made to Building and Appliance Office staff, commissioners, and interested public. While some proposals met with little concern from staff and public, others were more controversial. The staff have the proposals and follow-up information has been provided as requested.

During the Alternative Calculation Method Manual review process, Chapter 5 was successfully reviewed, and numerous comments and suggestions delivered to staff. While the primary purpose of the Alternative Calculation Method review was to build upon work being done in the EnergyPlus arena, the work scope had a specific limitation that focused on Chapter 5, which covers the certification tests. Many of the issues surrounding EnergyPlus occur in Chapter 2, which covers program capabilities, and Chapter 3, covering optional capabilities. Further work in these chapters would be necessary to ensure a smoother transition into advanced tools such as EnergyPlus.

Benefits to California

The California Energy Commission initiated and continues to update building energy efficiency standards to emphasize energy efficiency measures that:

- Save energy at peak periods and seasons.
- Improve the quality of installation of energy efficiency measures.
- Incorporate recent publicly funded building science research.
- Encourage collaboration with California utilities to incorporate results of appropriate market incentives programs for specific technologies.

These building energy standards and those for energy-efficient appliances are estimated to have saved more than $56 billion in electricity and natural gas costs since 1978. By incorporating new energy-efficient technologies and measures—potentially including the technologies covered in this report—it is estimated the standards will save an additional $23 billion by 2013.

1.0 Product Review

EnergySoft performed a detailed review of 17 research and development (R&D) reports submitted to the Public Interest Energy Research (PIER) division of the California Energy Commission (Energy Commission) and considered the technologies developed in this projects for inclusion in the Standards change proposals. (Note that some of the 17 reports are final, published reports and while others are available as drafts awaiting finalization or as published research papers.) This section presents the preliminary evaluations of each of the PIER reports and the recommendations as summarized below.

Table 1 lists the technologies evaluated and the recommended changes, which fall into these categories:

- Performance: Recommend implementing the technology as a credit under the performance compliance approach, which would entail changes in the *Nonresidential Alternative Calculation Method Manual* (ACM Manual)
- Mandatory Measures: Recommend changes in the mandatory measures sections of the Standards
- Prescriptive: Recommend changes in the prescriptive sections of the Standards
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Hotel Bathroom Lighting	Mandatory Measures
Downlight Systems	None
Integrated Classroom Lighting	Prescriptive
Bi-level Stairwell Fixtures	Prescriptive
HID Electronic Ballasts	None
Prioritized R&D Standards Connections	All
Performance Monitoring Specifications	Testing
Large Commercial Buildings Distribution Systems	None
Displacement Ventilation	Performance
Natural Ventilation	Performance
Underfloor Air Distribution Systems	Performance

1.1. Fault Detection and Diagnostics for Rooftop Air Conditioners

Contract Number: 400-99-011
Report Number: 500-03-096-A1
Project Report: http://www.energy.ca.gov/reports/2003-11-18_500-03-096-A1.PDF

1.1.1. Summary

Packaged rooftop air conditioners are the most poorly maintained of all heating, ventilation, and air conditioning (HVAC) systems. In California, they account for about 54% of the total HVAC energy used by the commercial sector. In this project, a Purdue research team developed thermo-fluids based fault detection and diagnostic (FDD) methods that can pinpoint five common packaged rooftop air conditioner maintenance problems.

The FDD technology is designed to automatically detect faults in packaged rooftop air conditioning systems and to provide diagnostic information to an outside source. The basic principle here is that maintaining optimal operation will enhance energy efficiency over the life of the system.

1.1.2. 2008 Standards Change Possibilities

Given that this technology is in the early stages of industry implementation, EnergySoft would not recommend making the FDD method a mandatory or prescriptive measure at this time. Instead, it is recommended that FDD be handled as a performance-based credit—similar to the current handling of thermostatic expansion valves (TXVs). It is also recommended to provide a credit in the functional testing stage of system implementation that occurs once an FDD enabled system is installed.

In terms of the performance method, modeling currently assumes that the packaged air conditioner mechanical system works perfectly, no faults exist, and the system always runs at peak efficiency. To implement this technology, the model would apply the same principle now applied to TXV modeling. That is, the model would assume some level of degradation in system performance as the default operating assumption. After application of the FDD technology, the model would assume the system runs at peak efficiency, acting on the assumption that the FDD will alert the owner or maintenance staff to the need for repairs.

The FDD method would also be applicable the Certificate of Acceptance (COA) functional testing requirements. Currently, Title 24 requires that a series of tests be performed to verify proper operation of the packaged systems. In applications that utilize the FDD technology, this functional testing would be simplified to reflect the self-diagnosing feature of this product.

1.2. Fault Detection and Diagnostics for Air Handling Units and Variable Air Volume Boxes

Contract Number: 400-99-011
Report Number: 500-03-096-A3
Project Report: http://www.energy.ca.gov/reports/2003-11-18_500-03-096-A3.PDF

1.2.1. Summary

Maintenance problems with built-up air handling units (AHUs) and variable air volume (VAV) boxes are often not detected by energy management systems because required data and analytical tools are not available. Because of the large volume of data requiring analysis, it is most practical to conduct the analysis within the distributed unit controllers. This project developed diagnostic rules for AHUs and VAV boxes.

The FDD technology is designed to automatically detect faults in AHUs and VAV boxes and to provide diagnostic information to an outside source. The basic principle here is that maintaining optimal operation will enhance energy efficiency over the life of the system.

1.2.2. 2008 Standards Change Possibilities

The same comments made for the rooftop FDD systems above would apply to this technology. Once again, it would be premature to require the application as a mandatory measure. However it would be appropriate to offer a credit as both a performance-based measure and a COA measure. In the case of this technology, two areas would be impacted: air handler performance and VAV box performance.

1.3. Light-Emitting Diode (LED) Exterior Lighting

Project Number: 500-01-041-A2
Project Report: http://www.archenergy.com/lrp/products/ledhybrid.htm

1.3.1. Summary

Aiming to replace conventional outdoor exterior lighting with a more energy efficiency product, this project created the LED Hybrid Fixture. This fixture couples an LED lamp that uses 5 watts (W) of lighting all night long—costing only about $0.01/night—with a 60-W incandescent lamp that operates only during “occupied” periods. A 13-W compact fluorescent lamp (CFL) could be substituted for the incandescent lamp, but the low operating hours creates a long marginal payback for the CFL variation—nearly 10 years for residential applications and around 5 years for commercial—compared to using an incandescent lamp. As another disadvantage, the light level of the CFL at start-up may lag that of an incandescent. The LED Hybrid is expected to reduce energy consumption by 53% compared to a CFL and by 87% compared to a standard incandescent fixture.

1.3.2. 2008 Standards Change Possibilities

The 2005 Title 24 Standards require that outdoor lighting in nonresidential applications be tabulated and show compliance with a certain W/ft^2 allowance. Unlike indoor lighting, however, no credits are given for lighting controls on outdoor fixtures. While certain controls are mandatory, such as a photosensor or astronomical time clock and in some cases multi-level switching, no credit is provided for occupancy sensor–based control. Based upon the LED Hybrid’s 87% savings projected in this report, EnergySoft would recommend applying a 75% lighting power adjustment factor (PAF) for the use of this technology. While 87% may seem like the logical choice, it has always been past policy to reduce the control credits to account for user override and non-operational controls. Two possible scenarios illustrate the energy saving aspect of the hybrid:

- CFL-based design with lighting always on:

  10 lamps @ 15 W = 150 W

  10 hrs operation X 365 days x 150 W = 547.5 kWh/yr

- LED/Incandescent hybrid–based design:

  10 lamps @ 60 W = 600 W; adjusted by 0.75 PAF = 150 W

  10 hrs operation x 365 days x 600 watts x 13% = 284.7 kWh/yr

Hence, the two equivalent fixtures will both achieve the same level of code compliance; however, the LED Hybrid will use substantially less energy on an annual basis, justifying the PAF for the LED Hybrid.

1.3.3. Retrofit Fluorescent Dimming

Project Number: 500-01-041
Project Report: http://www.archenergy.com/lrp/products/controls.htm

1.3.4. Summary

This report addresses retrofits of existing luminaries to incorporate dimmable electronic ballasts that are more easily controlled by users.

1.3.5. 2008 Standards Change Possibilities

This PIER project provides a technology that is suitable for the retrofit of existing luminaries in buildings. However, the technology would have no applicability to the Standards, which primarily address new construction. It's highly likely that mandating the use of dimming ballasts in existing buildings would be outside the scope of the Standards. It is recommended that this measure be given consideration under the existing building standards proceedings, which are underway.

1.4. Load-Shedding Ballast

Project Number: 500-01-041-A6
Project Report: http://www.energy.ca.gov/reports/reports_500.html (Final report not posted at time of this writing.)

1.4.1. Summary

The load-shedding ballast enables lighting to be a cost-effective tool for electrical demand response. Building on the highly successful instant-start ballast platform, the load-shedding ballast is designed to keep costs low while maintaining the highest available energy efficiency among competing ballast types. The load-shedding ballast combines technology for dimming instant start–operated fluorescent lamps with a means of remote signaling that allows all such ballasts in an area to reduce power by 33% upon command. The ballast is signaled via a power line carrier so no additional wiring is required.

Achieving control over an area greater than 10,000 ft^2 (typically containing more than 100 ballasts) from a single point, the load-shedding ballast aggregates the fluorescent lighting load, creating an easily controlled demand resource. The controller, which signals the ballasts in an area, can be set up to receive a load-shedding signal directly from a utility or independent system operator or from the building's energy management system to reduce the building's peak demand. Based on an anticipated incremental cost of $9 per ballast and a national average of electric rates, the simple payback on investment is approximately three years for new construction, remodeling, and replacement markets, with much faster payback in areas of the country where demand shortages frequently occur.

1.4.2. 2008 Standards Change Possibilities

The 2005 Standards includes a PAF credit in Table 146-A for the use of dimming electronic ballasts combined with automatic load control. The load-shedding ballast promoted in this report is similar to that technology. Although it does not dim the fixtures, it does achieve the load-shedding intent of the technology. Clearly the current credit achieves energy savings not only from the load shedding, but also from the dimming that will occur with occupant control at non-peak hours of the day. It would make sense to add an entry into Table 146-A to apply a credit for the load-shedding technology.

Dimmers alone in this table achieve a 10% PAF, and the load shedding with dimmers achieves a 25% PAF, so it would make sense that the load shedding alone should achieve a 15% PAF as a separate line item in this table.

1.5. Classroom Photosensors

Project Number: 500-01-041-A8
Project Report: http://www.archenergy.com/lrp/products/photosensor.htm

1.5.1. Summary

This project demonstrated a prototype of an advanced daylighting control system for classrooms that integrated dimming control with on/off switching and teacher control. The design of the system was based upon research into existing daylighting controls and common classroom designs, as well as on computer daylighting simulations, laboratory testing, and field testing. One of the primary points of emphasis in the system design was to greatly simplify the setup and calibration of the lighting control system.

1.5.2. 2008 Standards Change Possibilities

The 2005 Standards already provide credit for the system described in this report. Table 146-A provides PAFs for daylighting controls that use dimming, as well as for occupancy sensor controls. However, functional testing requirements specified in the Standards will require setup and testing of this system and documentation of the testing on the COA forms LTG-1-C, LTG-2-C, and LTG-3-C. It is recommended that the COAs incorporate streamlined procedures that will account for integrated systems, such as the system described in this report.

1.6. Hotel Bathroom Lighting

Project Number: 500-01-041-A10
Project Report: http://www.archenergy.com/lrp/products/bathroom.htm

1.6.1. Summary

The United States' estimated 4 million hotel guestrooms, which include approximately 365,000 rooms in California, present unique energy-saving opportunities. One of the key opportunities relates to the lighting of the hotel guestroom bathrooms—an opportunity that grows if numerous related institutional applications, such as dormitories and assisted living housing, are considered.

In this project, the California Lighting Technology Center research team developed a Smart Light Fixture (SLF), targeted at new construction or major renovations, to be produced and distributed by Speclight, a subsidiary of Lithonia Lighting. The SLF technology combines occupancy-based switching with an LED-based nightlight. The product reduces bathroom lighting energy use by about 50–75%.

1.6.2. 2008 Standards Change Possibilities

The current Title 24 Standards require that low efficacy lighting used in hotel bathroom lighting be controlled by an occupancy sensor. Because this product includes a low efficacy LED nightlight that is always activated, its use would not be permitted in the current code. Given the energy savings potential, it would make sense to add an exception to section 150(k)3, that would permit the use of this product in all bathroom applications. This proposed change would also impact residential applications, which is appropriate, as the SLF is very likely to also be suitable for home use.

1.7. Downlight Systems

Project Number: 500-01-041
Project Report: http://www.archenergy.com/lrp/products/downlight.htm
Fact Sheet Number: CEC-500-2005-057-FS, http://www.energy.ca.gov/2005publications/CEC-500-2005-057/CEC-500-2005-057-FS.PDF

1.7.1. Summary

A large majority of the downlights currently being installed in the residential sector use inefficient incandescent sources. In the commercial sector, most of the downlighting currently being installed use CFLs, but a large existing stock of incandescent downlights remains in operation. One of the primary objectives of this project was to provide consumers and facility managers with a relatively straightforward mechanism to convert incandescent downlighting to CFLs.

1.7.2. 2008 Standards Change Possibilities

This PIER project developed a technology suitable for the retrofit of existing luminaries in buildings. However, it would have no applicability to the Standards, which primarily address new construction. There might be some possibility that the Standards could mandate the retrofit of existing downlights. However, such a mandate would not really be consistent with the theme of the Standards, which is based more on lighting power density than on technology. Rather, it is recommended that this measure be considered under the existing building standards proceedings which are underway.

1.8. Integrated Classroom Lighting

Project Number: 500-01-041-A14
Project Report: http://www.archenergy.com/lrp/products/classroom.htm
Fact Sheet Number: CEC-500-2005-047-FS, http://www.energy.ca.gov/2005publications/CEC-500-2005-047/CEC-500-2005-047-FS.PDF

1.8.1. Summary

With input from representatives of the Collaborative for High Performance Schools, Finelite Inc. used a combination of best practices and new technologies to develop and test an integrated classroom lighting system (ICLS) for K–12 classrooms. The basic ICLS includes indirect luminaires with energy efficient T-8 lamps and electronic ballast, 96% reflective material within the fixture, a teacher control center located at the front of the classroom, and plug-and-play components.

1.8.2. 2008 Standards Change Possibilities

The integrated nature of the ICLS presents a major advantage. Title 24 already recognizes occupancy sensor/dimming control credits in classrooms, so no additional credit is likely to be given. The uplighting nature of the system could potentially reduce the LPD needed in a classroom; however the 2005 Standards change already reduced LPD allowances for classroom by 25%. It would require additional research to justify an additional LPD reduction in classrooms for the 2008 Standards. It is recommended that COA procedures be streamlined for the ICLS to recognize the integrated nature and reduce field testing time.

1.9. Bi-Level Stairwell Fixtures

Project Number: 500-01-041-A16
Project Report: http://www.archenergy.com/lrp/products/bilevel.htm

1.9.1. Summary

To address the desire for more light in stairwells when needed and less light when not needed, a new energy-saving, bi-level stairwell lighting fixture has been developed. The fixture meets code minimums when stairwells are not occupied and can increase light levels automatically when controls sense that occupants are entering the stairwell.

Four buildings were selected for testing based on how often the stairwells were used by occupants. Baseline measurements were taken prior to the installation of the bi-level stairwell fixtures. In these four buildings, building owners saved between 38–49% of lighting energy on 24-hour weekdays and between 47–67% on weekend days. The amount of time in dimmed mode ranged from 62–82% during weekdays and from 85–97% on weekends. The energy savings from the application of bi-level technologies to stairwells at the four test sites ranged from 40–60%.

1.9.2. 2008 Standards Change Possibilities

The current Title 24 Standards offer a PAF credit for bi-level illumination controls in hotel/motel corridors. This credit provides for a 25% adjustment to the installed LPD for the use of controls similar to those provided in this study. As a minimum, the change proposed here would alter Table 146-A PAF to create a control credit for the use of bi-level illumination in stairwells. In addition, it may include a change in the mandatory measures section of the standards to mandate bi-level illumination in stairwells. Such a change would not necessarily mandate the use of this type of fixture, since standard occupancy sensors could be used, but it would certainly save a considerable amount of energy in these applications. It is recommended that this issue be discussed with Standards Office staff prior to development of the final Measure Information Template to ensure this goes in the right direction.

1.10. High-Intensity Discharge (HID) Electronic Ballasts

Project Number: 500-01-041-A18
Project Report: http://www.archenergy.com/lrp/products/hid.htm

1.10.1. Summary

The past 10 years have seen a significant advancement in the technologies associated with HID lamps, including the incorporation of ceramic lamp envelopes and the ability to construct lamps with very exact dimensions. These advances have permitted the development of low-wattage metal halide sources that offer light output comparable to less-efficient point-source technologies, such as incandescent and halogen lamps. These new metal halide sources therefore have the opportunity for use in retail and commercial applications.

Magnetic ballasts have traditionally ballasted metal halide sources. Electronic ballasts have been available, but their market penetration has been limited due to size, cost, and efficiency issues. Recent developments in electronic circuitry have resulted in new technologies that seem to overcome these barriers. Further, the new electronic ballast technology provides variable light control—a feature that expands the opportunity of the new electronic ballast to reduce lighting loads in spaces that have supplemental daylight.

1.10.2. 2008 Standards Change Possibilities

It is expected that in the next few years, the electronically ballasted HID light sources will become more mainstream in the industry, due to the energy savings potential. One possibility would be to consider changes to Standards for LPD levels in buildings with certain occupancy types where this technology might be applied. However, that change would probably require a considerable amount of study, as well as a clear definition of market penetration of this technology.

It was initially recommended that this type of technology be included in the Measure Information Template and incorporated into Appendix NB, Illuminance Categories and Luminaire Power, of the Nonresidential ACM Manual. This would provide default wattages to be used in compliance calculations for this type of technology.

However, follow-on work done under task 3 of this project determined that Appendix NB already contains sufficient information and that this information is consistent with the outcome of this study. Therefore, no Measure Information Template is recommended relating to this study.

1.11. Prioritized R&D Standards Connections

Project Number: 500-01-041-A28
Project Report: http://www.archenergy.com/lrp/products/codes.htm

1.11.1. Summary

The purpose of this report was to facilitate a discussion of each project's potential to influence the future development of efficiency standards. Before being considered as a basis for code development, a technology must have a market track record, be readily available in the market, demonstrate adequate and consistent energy savings, and be non-proprietary in nature. Since most of the LRP projects are in the final design or early marketing stages, they need more promotional efforts to establish market presence before any code revisions can be undertaken.

Utility incentives are a good way to establish market presence. This project therefore considered the prospects for the adoption of technologies resulting from PIER's lighting research programs into an incentive program run by California utilities. Four factors were analyzed:

- Opportunity for code improvement
- Total resource cost ratio
- Peak demand reduction cost
- Strategic benefits

Most of the LRP projects were designed to cost-effectively reduce energy consumption, and several would also be cost-effective in reducing peak electrical demand when compared to existing sources of demand reduction.

1.11.2. 2008 Standards Change Possibilities

Most of the recommendations and conclusions in this project have been incorporated into the relevant sections of this report, in the form of specific recommendations for Standards changes. In a few cases, the project considered technologies for retrofit or residential applications. The current report, which focuses on nonresidential new construction, makes no recommendations about those retrofit or residential technologies.

1.12. Performance Monitoring Specifications

Project Number: 500-03-022
Project Report: http://cbs.lbl.gov/performance-monitoring/specifications

1.12.1. Summary

In collaboration with building owners, property managers and system vendors, LBNL is working to develop a specification for energy-oriented performance monitoring capabilities for commercial buildings that can be implemented either as part of an energy management control system (EMCS), an energy information system (EIS), or as a standalone system. The aim is to produce a specification that will be adopted by both private and public owners and managers and can be bid competitively by vendors.

1.12.2. 2008 Standards Change Possibilities

The most logical application of the protocols developed here would be in the COA area of the Standards. Current Title 24 requires functional testing of building systems prior to receiving final occupancy. The monitoring specifications developed as part of this report can be used to satisfy this testing requirement. In most applications, measurement equipment will be installed on a system at completion, and once completed, will be removed. Specifying that measurement equipment remain in the building, as outlined in this report, will not add to the amount of work performed by the HVAC contractor, and will provide the building owner means for ongoing measurement and presumably evaluation of the building performance. This same type of system could tie into the FDD approach as outlined earlier in this report.

1.13. Large Commercial Buildings Distribution Systems

Project Number: 50-03-097
Project Report: http://www.energy.ca.gov/reports/2003-11-20_500-03-097F-A08.PDF

1.13.1. Summary

Reducing duct leakage or other thermal losses from duct systems in large commercial buildings offers the potential for significant energy savings. However, California Title 24 has no provisions to credit energy efficient duct systems in these buildings, largely due to the lack of readily available simulation tools to demonstrate the energy saving benefits associated with efficient duct systems in large commercial buildings.

The overall goal of the Efficient Distribution Systems (EDS) project within the PIER High Performance Commercial Building Systems Program is to bridge the gaps in current duct thermal performance modeling capabilities and to expand understanding of duct thermal performance in California large commercial buildings. As steps toward this goal, the EDS project strategy involves two parts:

- Developing a whole-building energy simulation approach for analyzing duct thermal performance in large commercial buildings
- Using the simulation tool to identify the energy impacts of duct leakage in California large commercial buildings to support future recommendations related to duct performance in the Title 24 Energy Efficiency Standards for Nonresidential Buildings

1.13.2. 2008 Standards Change Possibilities

In the 2005 Standards, significant changes were made to computer models of nonresidential ducts in small commercial buildings, thanks to work performed by LBNL on the study of this issue. However, it appears that in large commercial applications, a number of hurdles prevent the implementation computer models the short term. Specifically, testing protocols for these types of systems will be too complex to be cost effective. In addition, the current computer modeling tools will require significant overhaul to accommodate the complexity of modeling such systems. As a result, LBNL has agreed that a Standards change proposal for 2008 is premature. It is recommended that this issue perhaps be considered for the 2011 Standards.

1.14. Displacement Ventilation

Project Number: 500-03-097-A9
Project Report: http://www.energy.ca.gov/reports/2003-11-20_500-03-097F-A09.PDF

1.14.1. Summary

The goal of the research presented in this report is to develop a better understanding of the important parameters of ventilation system performance and to develop simplified convective heat transfer models. The general approach used seeks to capture the dominant physical processes for these problems with first-order precision and develop simple models that show the correct system behavior trends. Dimensional analyses, in conjunction with simple momentum and energy conservation, scaled-model experiments, and numerical simulations, are used to improve airflow and heat transfer rate predictions in both single- and multi-room ventilation systems. This work covered the three commonly used room ventilation modes: mixing, displacement, and cross-ventilation; this section focuses on displacement ventilation models.

The report also presents implementation of the displacement ventilation models in a building thermal simulation software tool and compares model predictions, experimental results, and complex simulation methods, clearly displaying the improved precision of the new models over that of currently available simple models.

1.14.2. 2008 Standards Change Possibilities

The simplified displacement ventilation models developed in this report are applicable to the EnergyPlus software program. The 2008 Standards development will be predicated on the DOE-2.1E software, and no models were developed from this report for use with DOE-2.1E. It is recommended that language be developed in the Nonresidential ACM Manual to facilitate the modeling and application of simplified DOE-2.1E versions of the new displacement ventilation models produced with EnergyPlus. There is no reason why the EnergyPlus software could not be used as a modeling tool for compliance and analysis. It is anticipated that the development of the 2011 Standards will probably utilize EnergyPlus, which would indicate usage of the software in about 2009. An implemented capability for simplified displacement ventilation system modeling in 2008 will facilitate a Standards change proposal for the advanced displacement ventilation in 2011.

1.15. Natural Ventilation

Project Number: 500-03-097-A9
Project Report: http://www.energy.ca.gov/reports/2003-11-20_500-03-097F-A09.PDF

1.15.1. Summary

The goal of the research presented in this thesis is to develop a better understanding of the important parameters of ventilation system performance and to develop simplified convective heat transfer models. The general approach used seeks to capture the dominant physical processes for these problems with first-order precision and develop simple models that show the correct system behavior trends. Dimensional analysis, in conjunction with simple momentum and energy conservation, scaled model experiments and numerical simulations, are used to improve airflow and heat transfer rate predictions in both single and multi room ventilation systems. This work covered the three commonly used room ventilation modes: mixing, displacement and cross-ventilation; this section focuses on natural ventilation.

The report also presents implementation of the natural ventilation models in a building thermal simulation software tool and compares model predictions, experimental results, and complex simulation methods, clearly displaying the improved precision of the new models over that of currently available simple models.

1.15.2. 2008 Standards Change Possibilities

The basic comments made above for the displacement ventilation models apply to the natural ventilation models. That is, the EnergySoft team recommends that Nonresidential ACM Manual modeling procedures to calculate cooling credits from natural ventilation be developed for inclusion into the 2008 Standards documents. This change is particularly important, given the strong interest in naturally ventilated buildings. Having tools available to study energy implications would be an important first step towards a Standards change proposal that will incorporate natural ventilation in commercial buildings.

1.16. Underfloor Air Distribution

Project Number: 500-01-035
Project Report: http://www.energy.ca.gov/reports/reports_500.html (Final report not posted at time of this writing.)
Information on the Center for the Built Environment's (CBE's) research on underfloor air distribution (UFAD) research is available at:
http://www.cbe.berkeley.edu/underfloorair/Default.htm

1.16.1. Summary

In the winter of 2004–2005, the Center for the Built Environment was invited to participate in a review of draft design and engineering guidelines for UFAD in buildings designed and/or operated by the U.S. General Services Administration (GSA). These guidelines are being developed by the Office of the Chief Architect, GSA, a member of the CBE Industry Consortium. To solicit broader industry input to the UFAD guidelines, GSA convened a UFAD roundtable meeting in Washington, D.C., on May 5, 2005, and published major meeting results in a brief bulletin, *GSA UFAD Interim Guidelines*. This GSA document is expected to be released soon. While the bulletin briefly covered all subjects addressed by the Roundtable, CBE submitted comments to GSA in the form of recommended design guidelines for topics that have been the focus of CBE research.

1.16.2. 2008 Standards Change Possibilities

The 2005 Nonresidential ACM Manual contains a brief section outlining modeling procedures for UFAD systems. Based upon the information provided by CBE, it is recommended that additional language be developed for the 2008 Nonresidential ACM manual to provide more detailed guidelines on modeling UFAD systems. This information would include zoning guidelines and cooling load and airflow calculations as outlined in the UFAD report.

2.0 Measure Information Templates

Based upon the 17 PIER research projects reviewed in task 2, Energy Soft developed 11 Measure Information Templates and submitted the templates for public consideration at a February 22, 2006 Standards Public Workshop meeting. Hyperlinks to those documents as formally presented at the workshop are listed in Table 2 below, along with the type of change included in the template.

Table 2: Hyperlinks to documents presented at the Standards Public Workshop

Template	Recommended Standard/ACM Change
Fault Detection and Diagnostics for Rooftop Air Conditioners	Performance
Fault Detection and Diagnostics for Air Handling Units & VAV Boxes	Performance
LED Exterior Lighting	Prescriptive
Load Shedding Ballast	Prescriptive
Hotel Bathroom Lighting	Mandatory Measures
Integrated Classroom Lighting	Prescriptive
Bi-level Stairwell Fixtures	Prescriptive
Performance Monitoring Specifications	Performance
Displacement Ventilation	Performance
Natural Ventilation	Performance
Underfloor Air Distribution Systems	Performance

Appendix A includes each of the templates as submitted. Also included in Appendix A are some post-workshop email communications related to several of the submitted templates. Appendix B includes the two PowerPoint presentations which were presented at the Standards workshop. The status of each of these Measure Information Templates is summarized below.

2.1. Fault Detection and Diagnostics for Rooftop Air Conditioners

Presentation of the FDD for rooftop systems was well received by workshop attendees. Manufacturer representatives were present, and provided comment on the protocols to be established by the Energy Commission to provide manufacturers credit for implementing FDD. This protocol should be outlined more specifically as part of the acceptance requirements.

2.2. Fault Detection and Diagnostics for Air Handling Units and VAV Boxes

Standards Office staff expressed concern over a lack of correlation between the FDD materials for air handlers and VAV and the field test data showing faults and problems with systems. Additional information has been forwarded to staff in this regard, and Mark Cherniak with the New Buildings Institute has also focused resources to address this issue, including researchers at the National Institute of Standards and Technology.

2.3. LED Exterior Lighting

The original Measure Information Template proposal developed suggested a credit be applied in the range of 75%, on the basis of upon information contained in the PIER report. After discussions with Standards Office staff, the proposed credit was reduced to 50%. Further discussion with staff after the meeting indicated a concern over the application of this technology to Nonresidential projects. Additional information was forwarded to staff that demonstrated that actual test projects are being conducted in both University of California campus applications and Death Valley National Park.

2.4. Load-Shedding Ballasts

Concerns from staff regarding the credit for load shedding ballasts were addressed during the development of the template. In particular, the requirement for a certain ballast efficacy was incorporated into the template as part of the acceptance criteria for the product.

2.5. Hotel Bathroom Lighting

The importance of the application of occupancy-based lighting in hotel bathrooms was reiterated at the workshop by Energy Commission Commissioner Arthur H. Rosenfeld, based upon personal experience. There was considerable discussion on the appropriate mechanism for addressing this issue and on encouraging the use of the LED-based occupancy sensor luminaries. Staff had indicated that language could be drafted that would accomplish this goal, but were hesitant to apply the exemption for low-wattage LEDs, as expressed in the template. The hope was to drive the efficacy of low-wattage LEDs above the 30 lumen per watt threshold.

2.6. Integrated Classroom Lighting

The suggestion of requiring reduced lighting power densities in classroom applications met with resistance from designers present at the meeting, who maintained that the LPDs should not be lowered because no appreciable change in technology had occurred in the last several years. In fact, this particular PIER project had demonstrated a significant change in technology. Staff discussions indicated that a better solution would be to eliminate the 20% credit for occupancy sensors in this application and mandate the sensors instead. The net outcome of this change is actually a 20% reduction in the effective allowed LPD, so that change will result in more energy savings than suggested in the template.

2.7. Bi-Level Stairwell Fixtures

The proposal for inclusion of credits for bi-level lighting in stairwells met with some industry concern regarding fire safety. Given that stairwells are used for fire egress purposes, and given the importance now placed upon these exits in a post-911 world, adequate lighting in a smoke filled stairwell was raised as an issue. It was explained that this technology was not being promoted as a mandatory requirement, but rather a feature offering an optional credit for the designer. Thus, egress issues would need to be addressed as part of the design.

2.8. Performance Monitoring Specifications

Because performance monitoring specifications template presented met with very little comment from the workshop attendees, it is difficult to determine if this performance monitoring will appear as a feature in the 2008 Standards. No comment from staff has been received on this proposal.

2.9. Displacement Ventilation

The presentation of the proposal for recognition of displacement ventilation was made in conjunction with the proposal for UFAD systems (below). While industry groups did not have any significant concerns with the template, adjustments to the template were made in consultation with CBE, as discussed under the UFAD topic below. The outstanding issues for both displacement ventilation and UFAD remain to be addressed by CBE.

2.10. Natural Ventilation

Few comments were raised during the workshop regarding the trade-off potential that might occur from the energy savings obtained from recognizing natural ventilation in the Standards. However, most attendees most seemed to recognize the need for some way to recognize the energy savings. Further discussions with the lead contractor for the 2008 Standards included the possibility of recognizing the technology for high performance buildings designed to exceed the Standards.

2.11. Underfloor Air Distribution

A number of issues arose with Measure Information Template for UFAD systems. By far the most contentious workshop issue presented was the suggestion that the 2008 Standards recognize more fully the use of UFAD systems. Prior to the workshop, through consultation with staff at the CBE, it was determined that the modeling methodology to be presented had several shortcomings. Building upon material produced by Constructive Technologies Group, the Measure Information Template used simplified weighting factors for energy transfer to the plenum space, which CBE determined to be inadequate. Through a joint effort with CBE, the presentation at the workshop suggested refinements to the template to rectify this issue.

Significant objections were raised by industry representatives before, during, and after the meetings in the form of letters and comments. Responses to these comments were addressed by CBE staff in the form of letters to the California Energy Commission. At this stage, Standards Office staff seemed to recognize the merits of this template. However, CBE still needs to develop more accurate weighting factors.

3.0 ACM Development Report

3.1. Errors and Corrections in the Test Language

A thorough review has been made of chapter 5 of the *2005 Nonresidential Alternative Calculation Method Manual.* Chapter 5 of this manual details all of the certification tests required by candidate software programs seeking approval as Alternative Calculation Methods.

The purpose of this review was to determine any errors or items needing correction relating to the certification tests. Appendix C provides a copy of chapter 5 in revision mode, including all the suggested changes. An electronic copy of this revised chapter has been provided to Standards staff for inclusion in the 2008 version of this manual.

3.2. Issues Surrounding EnergyPlus and the Tests

Several changes and additions will be necessary to provide more precise information needed to model the ACM tests with EnergyPlus. Each change is described here, with recommended language.

3.2.1. Materials

Each material on the list of materials needs an associated roughness value, as follows:

- VeryRough
- MediumRough
- Rough
- Smooth
- MediumSmooth
- VerySmooth

In addition, a more precise definition of the materials is needed, including the properties of Thermal Absorptance, Solar Absorptance and Visible Absorptance. Table 3 lists recommended additions to the definition of materials, with a footnote that all three absorptance values shall be set to 0.65.

Table 3: Recommended changes to materials definitions in ACM tests

Name	R-value	Thickness	Conductivity	Density	Specific Heat	Roughness
	(h-ft²-ºF/Btu)	(ft)	(Btu-ft/h-ft²-ºF)	(lb/ft³)	(Btu/lb-ºF)	
Asphalt Shingle & Siding	0.44	0.0208	0.04727	70	0.35	Rough
Building Paper, Permeable Felt	0.06	0.0001	0.00167	0	0	Smooth
Plywood 1/2 inch (in)	0.63	0.0417	0.0667	34	0.29	Smooth
Gypsum Board 1/2 in	0.45	0.0417	0.0926	50	0.2	VerySmooth
Built-up Roofing 3/8 in	0.33	0.0313	0.0939	70	0.35	Rough
Plywood 3/4 in	0.94	0.0625	0.0667	34	0.29	Smooth
Plywood 5/8 in	0.78	0.0521	0.0667	34	0.29	Smooth
Carpet with Fibrous Pad	2.08	0.0208	0.01	0	0.34	Rough
Plaster	0.47	0.0625	0.133	75	0.31	Smooth
Concrete Panel	0.17	0.5	2.9412	150	0.2	Smooth
Metal Deck	0.01	0.0017	6	171	0.21	Smooth
Heavy Wt. Undried Aggregate 2 in	0.22	0.1667	0.7576	140	0.2	Smooth
Heavy Wt. Undried Aggregate 4 in	0.44	0.3333	0.7576	140	0.2	Smooth
Heavy Wt. Undried Aggregate 6 in	0.66	0.5	0.7576	140	0.2	Smooth
Heavy Wt. Undried Aggregate 12 in	1.32	1	0.7576	140	0.2	Smooth
Air Layer 4 in or more, Horizontal Roof	0.92	0.3333	0.36228	0	0	Smooth
Logs 6 in	7.5	0.5	0.0667	32	0.33	Rough
Logs 8 in	10	0.6667	0.0667	32	0.33	Rough
Logs 10 in	12.49	0.8333	0.0667	32	0.33	Rough
Logs 12 in	14.99	1	0.0667	32	0.33	Rough
Logs 14 in	17.49	1.1667	0.0667	32	0.33	Rough
Logs 16 in	19.99	1.3333	0.0667	32	0.33	Rough
Earth 12 in	2	1	0.5	85	0.2	Rough
Vented crawlspace	6	1	0.16667	0	0	Rough
Stucco	0.18	0.0729	0.4167	116	0.2	MediumRough
Straw bale	28.8	1.9167	0.0666	7	0.39	Rough
Acoustic tile + Metal	0.5	0.0417	0.033	18	0.32	Rough
OSB 7/16 in	0.55	0.0365	0.0667	34	0.29	Smooth
Exterior Insulation	5	0.0833	0.01666	1.8	0.29	Smooth
Interior Insulation	5	0.0833	0.01666	1.8	0.29	Smooth
Cavity Insulation	3.5	0.0833	0.0238	0.6	0.17	Smooth
4" LW CMU	0.56	0.3333	0.59689	105	0.2	Smooth
5" LW CMU	0.71	0.4167	0.5848	105	0.2	Smooth
4" MW CMU	0.47	0.3333	0.71563	115	0.2	Smooth
5" MW CMU	0.58	0.4167	0.72016	115	0.2	Smooth
3" NW CMU	0.27	0.25	0.91376	125	0.2	Smooth
4" NW CMU	0.37	0.3333	0.90209	125	0.2	Smooth
5" NW CMU	0.47	0.4167	0.89454	125	0.2	Smooth

3" Clay Brick	0.4	0.25	0.625	130	0.19	Smooth
4" Clay Bick	0.54	0.3333	0.61856	130	0.19	Smooth
5" Clay Brick	0.67	0.4167	0.62642	130	0.19	Smooth
3" Concrete	0.19	0.25	1.30435	144	0.2	Smooth
4" Concrete	0.25	0.3333	1.33922	144	0.2	Smooth
5" Concrete	0.31	0.4167	1.33209	144	0.2	Smooth
6" Concrete	0.37	0.5	1.35314	144	0.2	Smooth
7" Concrete	0.43	0.5833	1.35015	144	0.2	Smooth
8" Concrete	0.5	0.6667	1.32974	144	0.2	Smooth
9" Concrete	0.56	0.75	1.343	144	0.2	Smooth
10" Concrete	0.62	0.8333	1.34281	144	0.2	Smooth
11" Concrete	0.69	0.9167	1.33147	144	0.2	Smooth
12" Concrete	0.74	1	1.3563	144	0.2	Smooth
12" LW CMU, Solid Grout	1.110784314	1	0.900264784	115	0.2	Smooth
12" LW CMU, Empty Cells	1.475581395	1	0.677698976	74	0.2	Smooth
12" LW CMU, Insulated Cells	2.483333333	1	0.402684564	74	0.2	Smooth
12" MW CMU, Solid Grout	1.001851852	1	0.998151571	119.5	0.2	Smooth
12" MW CMU, Empty Cells	1.323913043	1	0.755336617	78	0.2	Smooth
12" MW CMU, Insulated Cells	2.18030303	1	0.458651842	78	0.2	Smooth
12" NW CMU, Solid Grout	0.904385965	1	1.105722599	124	0.2	Smooth
12" NW CMU, Empty Cells	1.190816327	1	0.839760069	82.5	0.2	Smooth
12" NW CMU, Insulated Cells	1.927777778	1	0.518731988	82.5	0.2	Smooth
10" LW CMU, Solid Grout	0.968181818	0.83333333	0.860719875	113.4	0.2	Smooth
10" LW CMU, Empty Cells	1.323913043	0.83333333	0.629447181	75.6	0.2	Smooth
10" LW CMU, Insulated Cells	2.091176471	0.83333333	0.398499766	75.6	0.2	Smooth
10" MW CMU, Solid Grout	0.844915254	0.83333333	0.98629221	118.2	0.2	Smooth
10" MW CMU, Empty Cells	1.190816327	0.83333333	0.699800057	80.4	0.2	Smooth
10" MW CMU, Insulated Cells	1.852702703	0.83333333	0.449793338	80.4	0.2	Smooth
10" NW CMU, Solid Grout	0.762903226	0.83333333	1.092318534	123	0.2	Smooth
10" NW CMU, Empty Cells	1.073076923	0.83333333	0.776583035	85.2	0.2	Smooth
10" NW CMU, Insulated Cells	1.58902439	0.83333333	0.524430801	85.2	0.2	Smooth
8" LW CMU Solid Grout	0.762903226	0.66666667	0.873854827	113.25	0.2	Smooth
8" LW CMU Empty Cells	1.15	0.66666667	0.579710145	74.25	0.2	Smooth
8" LW CMU Insulated Cells	1.852702703	0.66666667	0.359834671	74.25	0.2	Smooth
8" MW CMU Solid Grout	0.688461538	0.66666667	0.968342644	117.75	0.2	Smooth

8" MW CMU Empty Cells	1.036792453	0.66666667	0.643008796	78.75	0.2	Smooth
8" MW CMU Insulated Cells	1.58902439	0.66666667	0.419544641	78.75	0.2	Smooth
8" NW CMU Solid Grout	0.599275362	0.66666667	1.112454655	122.25	0.2	Smooth
8" NW CMU Empty Cells	1.036792453	0.66666667	0.643008796	83.25	0.2	Smooth
8" NW CMU Insulated Cells	1.422727273	0.66666667	0.4685836	83.25	0.2	Smooth
8" Clay Unit, Solid Grout	0.904385965	0.66666667	0.7371484	113.25	0.19	Smooth
8" Clay Unit, Empty Cells	1.277659574	0.66666667	0.521787399	85.5	0.19	Smooth
8" Clay Unit Insulated Cells	1.714102564	0.66666667	0.388930441	85.5	0.19	Smooth
6" LW CMU Solid Grout	0.620588235	0.5	0.805687204	109	0.2	Smooth
6" LW CMU Empty Cells	1.001851852	0.5	0.499075786	79	0.2	Smooth
6" LW CMU Insulated Cells	1.422727273	0.5	0.3514377	79	0.2	Smooth
6" MW CMU Solid Grout	0.538888889	0.5	0.927835052	114	0.2	Smooth
6" MW CMU Empty Cells	0.874137931	0.5	0.57199211	84	0.2	Smooth
6" MW CMU Insulated Cells	1.233333333	0.5	0.405405405	84	0.2	Smooth
6" NW CMU Solid Grout	0.465789474	0.5	1.073446328	119	0.2	Smooth
6" NW CMU Empty Cells	0.789344262	0.5	0.633437175	89	0.2	Smooth
6" NW CMU Insulated Cells	1.073076923	0.5	0.465949821	89	0.2	Smooth
6" Clay Unit, Solid Grout	0.688461538	0.5	0.726256983	111	0.19	Smooth
6" Clay Unit, Empty Cells	1.073076923	0.5	0.465949821	86	0.19	Smooth
6" Clay Unit, Insulated Cells	1.372222222	0.5	0.36437247	86	0.19	Smooth

Source: EnergySoft

* Thermal Absorptance, Solar Absorptance and Visible Absorptance = 0.65

3.2.2. Hot Water Systems

The ACM needs to specify a leaving water temperature for any system that utilizes a boiler. It is suggested that 180°F be used.

3.2.3. Cooling Towers

More precise information is needed for two-speed cooling towers when running on low speed, including information on capacity, airflow, and power consumption at low speed. For simplicity, it is suggested that these all be set at 50%. There is also a need to specify the capacity of the cooling towers when they run in a strictly convective mode. It is suggested that the capacity be set to 20%.

3.2.4. Glazing

EnergyPlus requires that a window be created from layers built up with specific properties and that the window frame be input in the zone description to determine conductance. These requirements are a big problem, since the Standards for Title 24 purposes are structured around National Fenestration Rating Council (NFRC) ratings, such as U-Factor, SHGC and VT. It is suggested that this issue be tied into the work being done by Architectural Energy Corporation (AEC) for the 2008 Standards on using the Window 5-layer approach.

3.2.5. Schedules

EnergyPlus requires specification of an "Activity Level Schedule" in terms of watts per person to describe occupant heat gain. A unique schedule will need to be specified for all unique space occupancy types, since the Btu/hr-occ varies by occupancy.

3.3. DOE-2 Input Files for Certification Tests

Three sets of DOE-2 input files have been created to date to describe each ACM test case listed in chapter 5 of the ACM Manual. The first set of input files were generated with the California Energy Commission's public domain tool, Perform 2005. A previous version of these files, generated with Perform 2001 (certified for the 2001 Standards) were provided to Jeff Hirsch, who produced a variation of these input files with the DOE-2.2 software tool for the 2001 Standards. This set of input files, as well as the 2005 files, circulated to LBNL, and the third set of input files were created by Joe Huang based upon information in these files.

Needless to say, this can be a confusing matter. As it currently stands, however, there are only two sets of 2005 Standards based input files; the LBNL files and the Perform 2005 files. Hirsch has yet to submit 2005 input files.

The two sets of files are in very different formats. The LBNL files use a feature in DOE-2 named "include" which permits a file to be broken down into pieces. Once each piece of the file is created, a master file then uses the include command, which instructs the software to read in those pieces. The main advantage of this approach is that commonly used pieces of the file that do not change can be created once. As an example, the Joint Appendix IV specifications for construction assemblies are static, and hence each input file can draw from the same base of construction assemblies. Maintenance is greatly reduced with this approach, since the include file relating to the construction assemblies is created and tested only once.

The set of files generated with Perform 2005 are in a more common format that places the entire building description in a single file. Hence, rather than including common pieces such as construction assemblies into the file, the entire description of construction assemblies pertaining to the building are included in the file itself. There are several advantages to this approach over the include approach. The first is that unnecessary pieces are not included into the file; for example, the include approach will read in all construction assemblies pertaining to all tests, whereas Perform 2005 only writes construction assembly descriptions pertaining to that particular test. The second advantage is that one need simply scan through a single file to ascertain if the correct information has been simulated in the test, while in the include approach, the information may be contained in as many as five or six different files if the user has not produced an single "echo" file of the include batch simulation. In addition, the include approach means the reviewer will need to trace the logic for each to determine which files those are, since the include information is different for each test.

Both approaches have advantages and disadvantages, so it is difficult to determine which approach is better. It is recommended that individual vendors be permitted to submit files in either format, depending upon the capabilities of their tools. A second question pertains to which approach the California Energy Commission should use for the in-house certification files. This question hinges on the maintenance and revisions of the files as progressive Standards changes come about. With the 2008 Standards looming, the certification test files will no doubt require revisions and updating.

Two approaches exist for revisions to the ACM test files. One is to manually edit the test files created by LBNL to reflect the 2008 changes. This will require someone with knowledge of the DOE-2 Building Description Language, as well as a good knowledge of the 2008 Standards changes. In past iterations of the Standards, staff has not normally performed this function. In fact, nobody has performed this function.

The second approach is to use the Perform 2005 software tool, as modified for the 2008 changes, as the basis of the test file generation. This approach is going to require a proactive approach to the updating of the Perform tool, as the Standards progress. In past years, this task has been accomplished at the end of the Standards development cycle. The suggestion here is that this be done early, once the new ACM language and Standards language is known. This will permit staff to evaluate the impacts of the Standards changes and to create a revised set of test files based upon those decisions.

3.4. HVAC Equipment in the Test Files

The ACM Manual appendix provides specific system sizes for each proposed HVAC system for each test. The sheer number of systems listed here makes this portion of the certification tests onerous. In fact, the number of systems is more a test of the ACM vendor's ability to follow the input guidelines, than a test of ACM capabilities. It is suggested that this appendix be significantly simplified by reducing the number of systems to the bare minimum, with the exception of the tests designed to test ACM sizing capabilities.

One discussion centered on the idea of self-sizing the HVAC system on each test, which would appear to simplify the problem. However, self-sizing will introduce a whole new layer of issues surrounding the specific algorithms used by each ACM to size equipment. Rather than introducing sizing issues into all the tests, it is best to keep this as a separate set of tests for ACM sizing. For this reason, it is recommended that a set of fixed system sizes be used that only vary by building type. The result would be a set of five fixed system sizes for the proposed building as detailed in Table 4. System sizes given in this table have been sized to reasonably meet the load for the tests, without the gross oversizing that currently exists in the ACM test systems.

Table 4: Recommended fixed system sizes for various building types

Building Type	Cooling Capacity	EER	SEER	Heating Capacity	AFUE	CFM	BHP
Prototype A	156,000	11		200,000	0.8	5,200	4
Prototype C							
VAV Systems	240,000	n/a	n/a	n/a	n/a	8,000	8
FPFC Systems	108,000	n/a	n/a	n/a	n/a	3,600	3
Prototype B	384,000	10		n/a	n/a	12,800	12
Prototype D	60,000	11	13	100,000	0.8	2,000	1

Source: EnergySoft

In the case of the Standard Design, language in chapter 5 is written such that the HVAC system is auto-generated by the candidate ACM:

> The ACM shall automatically define the standard design; determine the proper capacity of the HVAC equipment for the standard design; adjust the HVAC capacity of the standard design in accordance with the reference method; and automatically run the standard design to establish the energy budget.

One approach here would be to include tables that specify what size that system should be. However, this approach would introduce the same complexities that now exist for the proposed building. It is suggested that this language of self-sizing for the Standard system remain, thus giving the candidate ACM some flexibility in regards to the sizing algorithms used. What is important, however, is maintaining the language that requires the system be sized to meet the load.

> The reference method does not allow for undersized systems to be simulated for compliance purposes. ACMs shall also model adequately sized HVAC systems. Compliance runs that result in undersized equipment or equipment that cannot meet the heating or cooling loads for a significant fraction of the simulated run shall not be approved for compliance purposes. For ACMs that report the hours that loads are not met or the hours outside of throttling range, reports shall indicate that these hours are less than 10% of the hours of a year for each and every test in order for an ACM to qualify for approval.

3.5. DOE-2.2 Issues Raised

This section will address issues raised in the letter from Jeff Hirsch dated October 28, 2004, to the California Energy Commission regarding issues in the ACM Manual that impacted the DOE-2.2 certification. Note that the two sections in that letter pertaining to issues related to the DOE-2.1E simulation engine have not been included in this report, since are outside this scope of work. Listed below are the original comments, followed by responses and comments.

3.5.1. Return Air Plenum

Section 2.3.1.2 Return Air Plenums states:

> Return air plenums are considered conditioned spaces and shall be modeled as part of the adjacent conditioned space.

The comment in the Hirsch letter concerning this section is as follows:

> It is not clear if this means that no return air plenums may be simulated, or simply that return air plenums must be considered conditioned space. Simulating return air plenums as part of the same space as the conditioned space would result in much higher loads to the conditioned space most likely increasing supply air flow requirements well beyond actual designs.

EnergySoft suggests changing the language in the ACM Manual to clarify this point and to be more consistent with the Standards, as follows:

> Return air plenums are considered indirectly conditioned spaces. The ACM may either model return air plenums as part of the conditioned space or model them using a separate input specific to return air plenums if this is an available capability of the tool.

3.5.2. Fenestration Issues

Concerning the sections on fenestration—Section 2.3.5.6 Fenestration Thermal Properties, Section 2.3.5.7 Solar Heat Gain Coefficient of Fenestration in Walls and Doors, and Section 2.3.5.8 Solar Heat Gain Coefficient of Fenestration in Roofs—the letter states:

> These sections require that all fenestration products be simulated using the DOE-2.1E simplified glazing methodology. This method uses a single coefficient, GLASS-CONDUCTANCE, to describe conductive losses and gains and a single coefficient, SHADING-COEF, to describe solar radiative gains. This procedure significantly overestimates solar gains at high angles of incidence for multi-pane or coated glass compared to the more accurate GLASS-TYPE-CODE method of simulating glazing thermal performance using the Window5 reference program to create glazing modeling information. Consequently, cooling loads in spaces are unrealistically high and energy efficiency measures that reduce solar gains do not yield realistic savings.

This issue is being addressed by Architectural Energy Corporation as part of the 2008 Standards development, and a solution that utilizes the Window 5 modeling approach has already been proposed.

3.5.3. Process Loads

Concerning Section 2.4.1.5 Process Loads, the letter states:

> This section provides requirements for process loads that are part of proposed projects. The requirements in this section are limited to direct loads in the space, such as natural gas or electric loads in a space like manufacturing or process heating equipment. However, it contains no guidance for handling hot and chilled water process loads. For proper simulation of central plant equipment, hot and chilled water process loads should be simulated for the proposed and standard designs. This is particularly important in buildings where the central plant sizing is greatly influenced by the process load requirements (hotels or facilities with laundry of food services facilities, hospitals and other health care facilities, and many other building types).

This is a very good point. Other process loads that might be on the equipment should be modeled to accurately simulate the performance of the equipment. One solution would be to add language in the ACM Manual that permits the modeling of these other process loads. However, this solution introduces the following two significant issues:

- This will introduce verification requirements for the plan to check personnel for the process loads.
- If the standard building does not have a chiller (as is the case in a low-rise building) then the ACM will have to create a chiller just for the process load to accurately model the standard building.

The latter issue is the main concern, as it affects the sizing, as well as the type, of chiller chosen in the standard building. For instance, for a building with a 300-ton centrifugal chiller and 100 tons of process, the standard building would model a 100-ton reciprocating chiller, generating a compliance credit for meeting the process load, since the building had the more efficient centrifugal chiller. It is suggested that this not be implemented without addressing the issue of receiving credit for meeting process loads with a more efficient piece of equipment.

3.5.4. Performance Curves for Gas Absorption and Electric Chillers

Concerning Section 2.5.3.16 Performance Curves for Gas Absorption and Electric Chillers, the letter states:

> This section prescribes performance curves for electric water chillers. In many several cases, capacity curves are not normalized to a value close to 1; this can cause big problems for some buildings since the specified capacity will never be available and part load capacity energy input is shifted on the PLR curve. This is made worst for the screw machines since its PLR curve also has significant normalization problems. Both these problems are worst when the reference building and proposed building use different equipment (one has central plant and the other packaged equipment) but in all cases the compliance results are questionable if these curves are used.

The performance curves used in the ACM are from ASHRAE 90.1, and were developed by Taylor Engineering. Since Taylor is in the process of working on the 2008 Standards with AEC, it would seem logical for Standards Office staff to direct Taylor to address this issue as part of the development.

3.5.5. System Supply Air Temperature Control

Concerning 2.5.3.10 System Supply Air Temperature Control, the letter states:
This section states that the standard design shall use the same supply air temperature control strategy and schedule as the proposed design. This presents at least three problems, each described below:

1. The proposed supply air temperature is outside of the range required for the standard design system: This is the most obvious problem. As an example, Figure N2-12 requires that the standard design supply air temperature match the proposed supply air temperature but not less than 50 degrees and not greater than 60 degrees. Anytime the proposed supply air temperature falls out of this range, this requirement is impossible to meet.
2. The supply air temperature set point is an energy efficiency measure: Underfloor air distribution systems rely on higher supply and return air temperatures to maximize the use of outside air economizers. Since these systems are designed with low static pressure, the penalty for higher fan energy due to supply air temperature is minimal, while the savings in mechanical cooling is significant. This can only be considered an energy efficiency measure if the proposed design supply air temperature is allowed to be reset to a much higher temperature than the standard design supply air temperature. This section prohibits such a control strategy.
3. The proposed design utilizes warmest zone reset: Section 5.3.5 describes an optional capability test for warmest zone reset control option. The DOE-2.1E file provided by the CEC utilizes COOL-CONTROL = WARMEST for the proposed design and uses COOL-CONTROL = OA-RESET for the standard design with a reset schedule meeting the requirements of Section 3.5.3.10. It is not clear if Section 3.5.3.10 requires that WARMEST be used for the proposed and standard designs.

This issue was raised in earlier sections of this document pertaining to underfloor and displacement systems. It is suggested that the language in this section be changed to address these three issues as follows:

> In chapter 2 of the ACM Manual, it is suggested that the supply air temperatures for conventional systems be fixed at 55 degrees. In tables N2-11 through N2-14, the following would be changed:

Min Supply Temp: ~~50 ≤ T ≤ 60 DEFAULT:~~ 55

4.0 Conclusions

The EnergySoft team screened 17 PIER projects for potential inclusion into the 2008 Standards. Of those, 11 showed sufficient merit to warrant the development of Measure Information Templates. During the Standards Public Workshop held February 22, 2006, a formal presentation was made to Energy Commission Standards Office staff, commissioners and interested members of the public, resulting in discussion and debate over the merits of each proposal. While some proposals met with little concern from staff and public, others were more controversial, and resulted in considerable discussions and follow-up letters from industry groups. The proposals are now in staff's hands, and additional supporting information has been provided as requested. No doubt, there will be more follow-up required in terms of finalized Standards and ACM language, which is scheduled to be started in fall 2008.

4.1. Recommendations

For the ACM Manual review process, chapter 5, which covers certification tests was successfully reviewed, and numerous comments and suggestions delivered to staff. While the primary purpose of the ACM review was to build on work in the EnergyPlus arena, the workscope for the review was limited to chapter 5. It is important to note that many of the issues surrounding EnergyPlus actually occur in chapter 2, which covers program capabilities, and chapter 3, covering optional capabilities. Further work in these chapters would be warranted to ensure a smoother transition into advanced tools such as EnergyPlus.

4.2. Benefits to California

The California Energy Commission initiated and continues to update building energy efficiency standards to emphasize energy efficiency measures that:

- Save energy at peak periods and seasons
- Improve the quality of installation of energy efficiency measures
- Incorporate recent publicly funded building science research
- Encourage collaboration with California utilities to incorporate results of appropriate market incentives programs for specific technologies

It's estimated that these Building Energy Standards (along with those for energy efficient appliances) have saved more than $56 billion in electricity and natural gas costs since 1978. With the incorporation of new energy efficient technologies and measures—potentially including the technologies covered in this reports—it is estimated the standards will save an additional $23 billion by 2013.

5.0 Glossary

AEC	Architectural Energy Corporation
AHU	air handling units
ACM	alternative calculation method
CBE	Center for the Built Environment
CFL	compact fluorescent lamp
COA	Certificate of Application
EIS	Energy Information System
EMCS	energy management control system
Energy Commission	California Energy Commission
FDD	fault detection and diagnostics
EDS	efficient distribution systems
GSA	General Services Administration
HID	high-intensity discharge
HVAC	heating, ventilation, and air conditioning
ICLS	integrated classroom lighting system
in	inch
LED	light-emitting diode
LPD	lighting power density
PAF	power adjustment factor
SLF	Smart Light Fixture
Standards	2008 Building Energy Efficiency Standards
TXV	thermostatic expansion valve
UFAD	underfloor air distribution
VAV	variable air volume
W	watt

Appendix A:

Copies of Submitted Measure Information Templates

Development of Recommendations to Integrate Emerging Technologies into the 2008 Nonresidential Standards

Appendix A

Copies of submitted Measure Information Templates

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CEC Agreement #: 500-05-003

Publication Number: (in process)
June 1, 2006

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Appendix A – Measure Information Templates

Fault Detection and Diagnostics for Rooftop Air Conditioners

2008 California Building Energy Efficiency Standards

PIER Program - EnergySoft, LLC January 05, 2006

Overview

Description	Packaged air conditioners are the most poorly maintained type of HVAC system. In California, they use about 54% of the HVAC energy in the commercial sector. The Purdue research team developed thermo-fluids based fault detection methods that can pinpoint five common maintenance problems. The FDD technology is designed to automatically detect faults in rooftop (packaged) air conditioning systems, and to provide diagnostic information to an outside source. The basic principal here is that by maintaining optimal operation of the system, energy efficiency will be achieved over the life of the system.
Type of Change	It is proposed that the FDD technology be incorporated into the Standards as both a Compliance Option in the Nonresidential Performance Method, and also as a feature related to the Acceptance Requirements. Two documents will require changes to incorporate this feature. Section 3 of the Nonresidential ACM Manual will require an additional section describing this feature, and Chapter 8 of the Nonresidential Manual where the Acceptance Requirements are described. In addition, software vendors will need to modify their ACM products to incorporate this feature, and to incorporate the appropriate messages on the PERF-1 form identifying both the feature, as well as the requirement for field verification via the Certificate of Acceptance.

Energy Benefits	The most obvious benefit of this feature will be long term energy savings on packaged systems due to optimum operation. This feature parallels the TXV feature implemented on split systems many years ago as an energy conservation measure in the Standards. Since air conditioner operation is one of the bigger energy use components during peak demand periods, the primary savings from this measure will occur during the peak demand periods. The potential for savings will be mainly in compressor energy consumption; since we typically assume that fans are operational during occupied hours, there would be a small energy savings potential on fan consumption related to filter maintenance. When we apply the TDV numbers to this feature, we will see a more significant benefit, since the air conditioning use typically occurs during high TDV periods. Just as in the case of the TXV, the FDD technology will result in a higher Coefficient Of Performance on the cooling compressor related to better maintenance practices.
Non-Energy Benefits	Three primary non-energy benefits result from the use of the FDD technology. The first will be lower operational and maintenance costs. Clearly, by maintaining optimal performance of the system, energy cost savings will occur over the life of the system. In addition, this product can actually decrease maintenance costs for a building owner by eliminating unnecessary maintenance costs. This same type of approach is now being incorporated into high-end automobiles and trucking fleets; these vehicles will actually monitor driving habits and engine performance, and extend maintenance periods in response to actual operation. The second area of impact will be equipment life. By maintaining operational peak efficiency, the life of the system, and in particular the compressor will be extended. The third area of benefit would be in property management. Organizations that manage multiple properties would perceive a huge benefit by having this portion of building maintenance automated. Just as in the example of operators of trucking fleets, having a system that will automate HVAC maintenance would have a huge market potential.
Environmental Impact	No perceived negative environmental impacts will result from this technology.

Technology Measures	Measure Availability and Cost FDD builds on technology used in the HVAC Service Assistant system that's now available from Honeywell (visit http://acrx.com/serviceassistant.cfm). Enhancements include an online user interface and exclusive use of temperature sensors for diagnostics, which makes installation easier. Honeywell is considering integrating the FDD technology into its more-advanced product offerings. The initial cost of this feature is about $300. Note that this does not involve any interaction with an Energy Management System, but functions as a standalone diagnostic feature. Annual energy savings from this feature ranged from $400 - $1,000 in the field test performed. Field sites schools in Woodland and Oakland (Zones 12 and 3) four restaurant sites in Sacramento and San Francisco (Zones 12 & 3) as well as retail stores in Anaheim and Rialto (Zones 8 & 10). Based upon the demonstrated savings, this technology has the potential for a payback period of less than one year. Clearly with this type of energy savings, other manufacturers will be entering this arena. In fact, once adequate market penetration exists, which should occur by 2011, it would be recommended to implement this as a mandatory measure, similar to Demand Control Ventilation. Useful Life, Persistence and Maintenance The FDD technology is designed to last the life of the equipment. The one unknown area related to persistence of this measure is not related to reliability of the product, but rather the reliability of the service operator who is notified of the fault. Since service operators are in the business of making money based upon service calls, there is no reason not to believe that maintenance would not be performed.
Performance Verification	Clearly the only way to assure installation of this measure is via the Acceptance Requirements. The most obvious parallel would be DCV controls in the 2005 Standards. While building departments are responsible for verifying the correct specification of this feature, final verification and commissioning occurs via the MECH-6-A Acceptance Certificate. One of the benefits of the FDD, however, is the ability to verify proper equipment performance, including such features as the economizers. Therefore, it would be recommended that the MECH-3-A and MECH-4-A be modified to simplify functional testing when this measure is included. Installer verification would then be simplified to the task of proper calibration and operation of the FDD feature, as opposed to the system itself.
Cost Effectiveness	The FDD technology has a payback period of less than one year. Clearly, with such a cost effective measure, this should really be a mandatory measure for packaged units. However, just as DCV controls were in their initial stages 10 years ago, this same technology does not enjoy widespread use yet. Therefore, this measure change has been proposed as a compliance option.

Analysis Tools	The current reference method, DOE-2.1E is proposed to be used as the basis of determining savings for this measure, although the procedures developed in this measure template could be applied to any certified Alternative Calculation Method. One of the problems that we have with our analysis tools is that they assume a perfectly functioning building. This technology demonstrates that, in reality, we are being way too generous with this assumption as regards the HVAC system. However, the current nonresidential reference method can be used to model a reasonable representation of this "broken" HVAC system. In fact, procedures are already in the Standards for modeling of TXV valves using the same concept. The system without the TXV valve is modeled as using more energy than the system with the TXV valve. It is recommended that we apply the same concept to the FDD feature.
Relationship to Other Measures	No other measures are impacted by this feature in the modeling.

Methodology

Since current practice in the industry is not to utilize FDD technology, and field data has shown that a high percentage of packaged systems have one or more faults, the baseline building assumption will include HVAC systems that do not include FDD. When the Standard building includes Packaged DX systems, they will be assumed to be "broken" in the same fashion as we do with TXVs. In fact, it is the recommendation of this measure template that we apply an identical approach to FDD technology as we do for TXVs. Hence, the Standard building under the performance method will have a 6% degradation factor applied to the cooling EIR. In addition, to account for the FDD impact on economizer operation, the economizer in the Standard building would be assumed to have a 10% degradation factor, only allowing 90% of outside air into the building.

If the proposed building includes the FDD, the cooling EIR would be restored to normal, and the economizer, if present, assumed to provide 100% outside air to the building.
In regards to the 10% degradation factor related to economizers, a conservative value was chosen. A field study on 503 rooftop units done by the New Buildings Institute (NBI) (see reference material at the end of this report) showed that 64% of the economizers to be faulty. This study includes 215 units surveyed by the California Energy Commission. Estimates in this report of energy savings by repairing the economizers were a 25% savings.

Note that this measure is not being proposed as a mandatory measure, nor as a prescriptive requirement. It is being proposed as a compliance option for building owners who choose to incorporate this feature. Given the large failure rate shown in the NBI report, and the fact that all sites that incorporated the FDD in the PIER study benefited, this measure offers excellent savings potential to building owners.

Analysis and Results

An FDD system uses sensors embedded in the RTU controller to monitor conditions at various points in the cooling cycle. The system's logic uses data such as ambient dry bulb temperature and the dry- and wet bulb temperatures of return, mixed, and supply air to predict normal operating temperatures—including evaporator temperature, suction superheat, condenser temperature, condenser subcooling, and compressor hot gas temperature—as well as differences in condenser and evaporator air temperatures. The FDD system then calculates the difference between monitored and expected temperatures and analyzes the data to determine what problems may be imminent and what actions should be taken. The device communicates this diagnostic information to the facilities Manager.

The new FDD system can detect a variety of problems in compressors, heat exchangers, expansion valves, and economizers, and other components. Field tests have shown not only how common these problems are but also how successful an FDD can be at detecting them. Roughly 71 percent—15 of the 21 systems studied—had some kind of problem that affected performance. Filter/drier restrictions plagued 11 of the systems, 10 had a low refrigerant charge and 8 suffered from both low charge and filter/drier restrictions.

Recommendations

The following is recommended language for the Nonresidential ACM Manual.

Equation N2-20 should be modified to include the term F_{fdd}

F_{fdd} Cooling system performance adjustment factor, default = 0.90. For packaged systems with FDD controls, F_{fdd} shall be 0.96.

Equation N2-1

$$\begin{aligned} EERnf_{EWB,ODB} &= 1.0452 \times EER_{EWB,ODB} \\ &+ 0.0115 \times EER_{EWB,ODB}{}^{2} \\ &+ 0.000251 \times EER_{EWB,ODB}{}^{3} \times F_{TXV} \times F_{AIR} \times F_{FDD} \end{aligned}$$

In section 2.5.2.6, the entire equation for calculating the COOLING-EIR has been omitted, so it would be suggested that the following language be added, which is based upon the previous ACM Manual:

Description: ACMs shall require the user to input the EER for all packaged cooling equipment that are not covered by DOE appliance standards.

ACMs shall also require the user to input the net cooling capacity, CAPa, at ARI conditions for all cooling equipment.

ACMs shall calculate the electrical input ratio, EIR, according to Equation N2-19

DOE Keyword: COOLING-EIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for The ACM shall require the user to input efficiency descriptors at ARI conditions for Proposed Design: all equipment documented in the plans and specifications for the building.

Default: Minimum EER as specified in the Appliance Efficiency Regulations.

Modeling Rules for Standard Design (New): For the reference method, the standard design shall assign the EER and EIR of each unit according to the applicable requirements of the Appliance Efficiency Standards or the Standards. The EIR of the equipment will be based on the proposed system with an EER that meets the applicable requirements of the Standards but has the same cooling capacity and ARI fan power as the unit selected for the proposed design.

Modeling Rules for The Standard Design (Existing Unchanged & Altered Existing): ACMs shall use the EER, EIR, and the ARI fan power of the existing system. EIR of the existing equipment must be based on the EER and the ARI fan power of the existing system. ACMs shall model the existing system as it occurs in the existing building. If the permit involves alterations, ACMs shall model the system before alterations.

2.5.3.7 Air Economizers

Description: The reference method is capable of simulating an economizer that: (1) modulates outside air and return rates to supply up to 100% of design supply air quantity as outside air; and, (2) modulates to a fixed position at which the minimum ventilation air is supplied when the economizer is not in operation. The reference method will simulate at least two types of economizers and all ACMs shall receive input for these two types of economizers:

1. Integrated. The economizer is capable of providing partial cooling, even when additional mechanical cooling is required to meet the remainder of the cooling load. The economizer is shut off when outside air temperature or enthalpy is greater than a fixed setpoint.

2. Nonintegrated/fixed set point. This strategy allows only the economizer to operate below a fixed outside air temperature set point. Above that set point, only the compressor can provide cooling.

The default for MAX-OA-FRACTION shall be 0.9 to represent imperfect operation of the economizer.

DOE Keyword: ECONO-LIMIT
ECONO-LOCKOUT
ECONO-LOW-LIMIT
MAX-OA-FRACTION

Chapter 3 should be modified with the following language:

3.3.18 Packaged System Fault Detection & Diagnosis

Description:	A nonresidential ACM may be approved with the optional capability of controls that allow for self detection and diagnostic of faults in packaged systems. This optional capability is only available for Packaged DX cooling systems.
DOE Keyword:	COOLING-EIR MAX-OA-FRACTION
Input Type:	Required
Tradeoffs:	Yes
Modeling Rules for Proposed Design:	ACMs shall model the optional feature of proposed design FDD controls as input by the user according to plans and specifications for the building. For systems with FDD controls the cooling system performance adjustment factor F_{fdd} in equationN2-20 shall be 0.96. The economizer MAX-OA-FRACTION keyword shall be 1.0.
Modeling Rules for Standard Design (New):	ACMs shall determine the standard design according to Table N2-10.
Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):	ACMs shall model the existing system as it occurs in the existing building. If the permit involves alterations, ACMs shall model the system before alterations.

Material for Compliance Manuals

It is recommended that only Chapter 8 of the Nonresidential Compliance Manual be changed to accommodate this measure since it will be dealt with as an Acceptance Requirement item. Additional information pertaining to the use of the FDD should be incorporated into the MECH-3-A form and simplifications made to the MECH-4-A.

Bibliography and Other Research

Information for this measure template has been taken from the PIER research project number 500-03-096-A1 report. This PIER report is available from the California Energy Commission's PIER website as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

The hyperlink for this project is as follows:

http://www.energy.ca.gov/reports/2003-11-18_500-03-096-A1.PDF

The field study by the New Buildings Institute on rooftop unit performance can be found at:

http://www.newbuildings.org/downloads/NWPCC_SmallHVAC_Report_R3_.pdf

Fault Detection and Diagnostics for Air Handling Units and VAV Boxes

2008 California Building Energy Efficiency Standards

PIER Program - EnergySoft, LLC January 05, 2006

Overview

Description

Maintenance problems with built-up air handlers and variable air volume boxes are often not detected by energy management systems because required data and analytical tools are not available. Because of the large volume of data requiring analysis it is most practical to conduct the analysis within the distributed unit controllers. Researchers at National Institute of Standards and Technology (NIST) have developed diagnostic rules for air-handling units (AHU) and variable air volume (VAV) boxes.

The Fault Detection and Diagnostic (FDD) system described here will provide operational performance data to the energy management system, allowing early correction of mechanical system faults.

Type of Change

It is proposed that the FDD technology be incorporated into the Standards as both a Compliance Option in the Nonresidential Performance Method, and also as a feature related to the Acceptance Requirements.

Two documents will require changes to incorporate this feature. Section 3 of the Nonresidential ACM Manual will require an additional section describing this feature, and Chapter 8 of the Nonresidential Manual where the Acceptance Requirements are described.

In addition, software vendors will need to modify their ACM products to incorporate this feature, and to incorporate the appropriate messages on the PERF-1 form identifying both the feature, as well as the requirement for field verification via the Certificate of Acceptance.

Energy Benefits

The most obvious benefit of this feature will be long term energy savings on air handlers and VAV boxes due to optimum operation. Since air conditioner operation is one of the bigger energy use components during peak demand periods, the primary savings from this measure will occur during the peak demand periods. The potential for savings will be in several areas of building energy use. Fan power consumption will be reduced due to proper operation of the air handler, as well as VAV boxes that are responding correctly to zone demand requirements. Cooling energy will be reduced due to proper operation of the VAV boxes since a VAV box that is providing too much air to a zone will end up overcooling the zone. This then results in wasted energy on the heating side, since the reheat coil will then need to be activated. In addition, pumping energy usage will be reduced as a result of not having to pump hot water out to the reheat coils.

Non-Energy Benefits

Two primary non-energy benefits result from the use of the FDD technology. The first will be lower operational costs. Clearly, by maintaining optimal performance of the system, energy cost savings will occur over the life of the system.

The second area of impact will be equipment life. By maintaining operational peak efficiency, the life of the system will be extended.

Environmental Impact

No perceived negative environmental impacts will result from this technology.

Technology Measures

Measure Availability and Cost

NIST worked with three major building control manufacturers to embed these rules in their respective controller products using the native programming language of each. A fourth manufacturer recently expressed interest in the next phase of development, which will entail testing at dozens of facilities to prove the reliability of the algorithms in different HVAC systems and facility types.

It is anticipated that this technology will add little initial cost to the system. However, there will be some expense in the commissioning of the system and training of onsite personnel.

Useful Life, Persistence and Maintenance

The FDD technology is designed to last the life of the equipment.

Performance Verification	The only way to assure installation of this measure is via the Acceptance Requirements. The most obvious parallel would be DCV controls in the 2005 Standards. While building departments are responsible for verifying the correct specification of this feature, final verification and commissioning occurs via the MECH-6-A Acceptance Certificate. One of the benefits of the FDD, however, is the ability to verify proper equipment performance, including such features as the economizers. Therefore, it would be recommended that the MECH-4-A and MECH-7-A be modified to simplify functional testing when this measure is included. Installer verification would then be simplified to the task of proper calibration and operation of the FDD feature, as opposed to the system itself.
Cost Effectiveness	A payback has yet to be determined for this FDD technology.
Analysis Tools	The current reference method, DOE-2.1E is proposed to be used as the basis of determining savings for this measure, although the procedures developed in this measure template could be applied to any certified Alternative Calculation Method. One of the problems that we have with our analysis tools is that they assume a perfectly functioning building. This technology demonstrates that, in reality, we are being way too generous with this assumption as regards the HVAC system. However, the current nonresidential reference method can be used to model a reasonable representation of this "broken" HVAC system. In fact, procedures are already in the Standards for modeling of TXV valves using the same concept. The system without the TXV valve is modeled as using more energy than the system with the TXV valve. It is recommended that we apply similar concepts to the FDD feature.
Relationship to Other Measures	No other measures are impacted by this feature in the modeling.

Methodology

Since current practice in the industry is not to utilize FDD technology, and field data has shown that a high percentage of AHUs and VAV boxes have one or more faults, the baseline building assumption will include HVAC systems that do not include FDD. When the Standard building includes Air Handling Units, the economizer will be assumed to have a performance degradation of 10%. Thus, the maximum outside air capability of the economizer will be 90%. In addition, if the Standard building includes VAV boxes, a 10% degradation factor will be assumed. The minimum airflow ratio of the VAV box, which is typically 30%, will be increased to 33%. Thus, these components are assumed to be "broken" in the same fashion as we do with TXVs.

If the proposed building includes the FDD, the economizer performance would be restored to the normal 100% position and the VAV boxes, if present, would operate at their as designed minimum flow ratio.

In regards to the 10% degradation factor related to economizers, a conservative value was chosen. A field study on 503 rooftop units done by the New Buildings Institute (NBI) (see reference material at the end of this report) showed that 64% of the economizers to be faulty.

This study includes 215 units surveyed by the California Energy Commission. Estimates in this report of energy savings by repairing the economizers were a 25% savings.

Note that this measure is not being proposed as a mandatory measure, nor as a prescriptive requirement. It is being proposed as a compliance option for building owners who choose to incorporate this feature. Given the large failure rate shown in the NBI report, and the fact that all sites that incorporated the FDD in the PIER study benefited, this measure offers excellent savings potential to building owners.

Analysis and Results

AHUs

The basis for the fault detection methodology is a set of expert rules used to assess the performance of the AHU. The tool developed from these rules is referred to as APAR (AHU Performance Assessment Rules). APAR uses control signals and occupancy information to identify the mode of operation of the AHU, thereby identifying a subset of the rules that specify temperature relationships that are applicable for that mode. The two main mode classifications are occupied and unoccupied. The 5 operating modes are summarized below:

- Mode 1: heating
- Mode 2: cooling with outdoor air
- Mode 3: mechanical cooling with 100 % outdoor air
- Mode 4: mechanical cooling with minimum outdoor air
- Mode 5: unknown

Because the direct digital control (DDC) output to the actuators of the heating and cooling coil valves and the mixing box dampers are known, the mode of operation can be ascertained. A fifth mode of operation referred to "unknown" operation has been defined and listed above. The unknown mode applies to the case in which the AHU is running in an occupied mode, but none of the control output relationships defined for Modes 1-4 are satisfied. The unknown mode could be associated with mode transitions and/or with faulty operation such as simultaneous heating and cooling. Once the mode of operation has been established, rules based on conservation of mass and energy can be used along with the sensor information that is typically available for controlling the AHUs.

VAV Boxes

The challenges presented in detecting and diagnosing faults in VAV boxes are similar to those encountered with other pieces of HVAC equipment. Generally there are very few sensors, making it difficult to ascertain what is happening in the device. Limitations associated with controller memory and communication capabilities further complicate the task. The number of different types of VAV boxes and lack of standardized control sequences add a final level of complexity to the challenge. This set of constraints is counterbalanced by the fact that VAV boxes are much more numerous than other pieces of HVAC equipment. For instance, buildings may have ten to fifteen times more VAV boxes than air-handling units. Hence, maintenance staffs would clearly benefit from a tool that assisted them in monitoring VAV box operation.

The needs and constraints described above have led to the development of VAV Box Performance Assessment Control Charts (VPACC), a fault detection tool that uses a small number of control charts to assess the performance of VAV boxes. The underlying approach, while developed for a specific type of VAV box and control sequence, is general in nature and can be adapted to other types of VAV boxes.

APAR and VPACC were evaluated using data from several different sources – an office building, a restaurant, and community college and university campuses, featuring constant- and variable-air-volume systems. Any evaluation using field data must contend with some inherent difficulties: reliance on sensor data to discern the true state of the system, the inability to report a "false positive" (an undetected fault), and ambiguity regarding what constitutes a fault. However, in this case consistent results across diverse testing environments gives a high level of confidence that the FDD tools will perform in an even greater variety of applications. Several faults were successfully detected and confirmed by building operations staff. Every site has been found to have at least one fault. Even though the sample size is small, these results appear to confirm the hypothesis that faults of the type that can be detected by these tools are common.

Recommendations

The following is recommended language for the Nonresidential ACM Manual.

2.5.3.12 Zone Terminal Controls

Description: ACMs shall be capable of modeling zone terminal controls with the following features:

- *Variable air volume (VAV).* Zone loads are met by varying amount of supply air to the zone.
- *Minimum box position.* The minimum supply air quantity of a VAV zone terminal control shall be set as a fixed amount per conditioned square foot or as a percent of peak supply air.
- *(Re)heating Coil*. ACMs shall be capable of modeling heating coils (hot water or electric) in zone terminal units. ACMs may allow users to choose whether or not to model heating coils.
- *Hydronic heating*. The ACM shall be able to model hydronic (hot water) zone heating.
- *Electric Heating*. The ACM shall be able to model electric resistance zone heating.

ACMs shall require the user to specify the above criteria for any zone terminal controls of the proposed system.

The keyword MIN-CFM-RATIO shall be the minimum box position times 1.1 (not to exceed 1.0) to reflect imperfect operation of the VAV box, unless FDD controls are installed.

DOE-2 Keyword(s) MIN-CFM-RATIO
ZONE-HEAT-SOURCE

Input Type	Required
Tradeoffs	Yes
Modeling Rules for Proposed Design:	The reference method models any zone terminal controls for the proposed design as input by the user according to the plans and specifications for the building. All ACMs that explicitly model variable air volume systems shall not allow any minimum box position to be smaller than the air flow per square foot needed to meet the minimum occupancy ventilation rate.
Modeling Rules for Standard Design (New & Altered Existing):	For systems 3 and 4, the ACM shall model zone terminal controls for the standard design with the following features: Variable volume cooling and fixed volume heating Minimum box position set equal to the larger of: a) 30% of the peak supply volume for the zone; or b) The air flow needed to meet the minimum zone ventilation rate; or c) 0.4 cfm per square foot of conditioned floor area of the zone. Hydronic heating.

2.5.3.7 Air Economizers

Description:

The reference method is capable of simulating an economizer that: (1) modulates
outside air and return rates to supply up to 100% of design supply air quantity as outside air; and, (2) modulates to a fixed position at which the minimum ventilation air is supplied when the economizer is not in operation. The reference method will simulate at least two types of economizers and all ACMs shall receive input for these two types of economizers:

1. Integrated. The economizer is capable of providing partial cooling, even when additional mechanical cooling is required to meet the remainder of the cooling load. The economizer is shut off when outside air temperature or enthalpy is greater than a fixed setpoint.

2. Nonintegrated/fixed set point. This strategy allows only the economizer to operate below a fixed outside air temperature set point. Above that set point, only the compressor can provide cooling.

The default for MAX-OA-FRACTION shall be 0.9 to represent imperfect operation of the economizer.

DOE Keyword:

ECONO-LIMIT
ECONO-LOCKOUT
ECONO-LOW-LIMIT
MAX-OA-FRACTION

Chapter 3 should be modified with the following language:

3.3.19 Air Handler and VAV Box Fault Detection & Diagnosis

Description:	A nonresidential ACM may be approved with the optional capability of controls that allow for self detection and diagnostic of faults in air handlers and variable air volume boxes.
DOE Keyword:	MIN-CFM-RATIO MAX-OA-FRACTION
Input Type:	Required
Tradeoffs:	Yes
Modeling Rules for Proposed Design:	ACMs shall model the optional feature of proposed design FDD controls as input by the user according to plans and specifications for the building. For systems with FDD controls the VAV box minimum flow ratio shall be the flow ratio as shown in plans and specifications. The economizer MAX-OA-FRACTION keyword shall be 1.0.
Modeling Rules for Standard Design (New):	ACMs shall determine the standard design according to Table N2-10.
Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):	ACMs shall model the existing system as it occurs in the existing building. If the permit involves alterations, ACMs shall model the system before alterations.

Material for Compliance Manuals

It is recommended that only Chapter 8 of the Nonresidential Compliance Manual be changed to accommodate this measure since it will be dealt with as an Acceptance Requirement item. Additional information pertaining to the use of the FDD should be incorporated into the MECH-7-A form and simplifications made to the MECH-4-A.

Bibliography and Other Research

Information for this measure template has been taken from the PIER research project number 500-03-096-A3 report. This PIER report is available from the California Energy Commission's PIER group as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

The hyperlink for this project is as follows:

http://www.energy.ca.gov/reports/2003-11-18_500-03-096-A3.PDF

The field study by the New Buildings Institute on rooftop unit performance can be found at:

http://www.newbuildings.org/downloads/NWPCC_SmallHVAC_Report_R3_.pdf

Communications related to this template

Bruce,

As a follow-up to our meeting the other day, you had asked for more support material on the FDD for VAV template I had provided. AEC/Taylor engineering prepared the attached case study for NBI that may be of interest in support of that proposal. They mention 10-30% savings.

http://www.archenergy.com/pier-fdd/market_connection/Proj7_Deliverables/FDDAlgorthimsCaseStudyFinal.pdf

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LED Exterior Lighting

2008 California Building Energy Efficiency Standards

PIER Program - EnergySoft, LLC

January 05, 2006

Overview

Description

The California Lighting Technology Center (CLTC) has developed and commercialized an LED Hybrid light fixture. These fixtures use LED arrays in conjunction with traditional incandescent or fluorescent sources. The entire fixture is controlled by a photocell that keeps all lights OFF during the day. At night, the photocell turns the fixture ON. The low wattage LED array stays on for the duration of the evening and provides low level 'ambient' illumination in the area around the fixture. When the motion sensor detects motion, it turns on the incandescent or fluorescent lamp for a short duration to raise the light output of the fixture to a level equal with standard outdoor fixtures.

It is expected that the primary application of this technology would be pedestrian hardscape areas, although it is quite plausible that manufacturers may develop additional applications that would benefit from the LED technology.

Type of Change

This change is proposed to be an addendum table to the Prescriptive Outdoor Lighting section of the Standards (147). An additional control credit table would be added which recognizes the type of lighting control described here, similar to the table 146-A Power Adjustment Factor table. In addition, performance criteria would be added in the mandatory measures section for the control requirements, as well as certification requirements for the controls.

Energy Benefits

The LED Hybrid Fixture uses 5 Watts of LED lighting all night long—costing only about $0.01/night—and 60 Watts of incandescent lighting during "occupied" periods. A 13-Watt compact fluorescent lamp (CFL) could be substituted for the incandescent lamp, but the low operating hours gives it a long marginal payback—nearly 10 years for residential applications and around 5 years for commercial —compared to using an incandescent lamp. Also, the light level of the CFL at start-up may lag that of an incandescent. The LED Hybrid is expected to reduce energy consumption by 53% compared to a CFL and 87% compared to a standard incandescent fixture.

While this proposal does not address the Residential Standards, it could also be considered to adopt this type of technology as meeting the high efficacy requirements for residential outdoor lighting.

Non-Energy Benefits	This technology will extend lamp life considerably, given the reduced operating hours that will occur. In addition, a significant reduction in light trespass will occur due to the low light output of the LED during unoccupied periods.
Environmental Impact	There are no perceived environmental impacts with the use of LED's and motion sensors on outdoor lighting.
Technology Measures	Measure Availability and Cost All of the components involved in this fixture have been commonly available in the marketplace for at least 10 years. Shaper Lighting, a division of Cooper Lighting, commercialized this fixture in December 2004, selling it for about $200. The Watt Stopper Company is in the tooling phase for another version of the LED Hybrid concept based on the popular residential PAR lamp security light. Useful Life, Persistence and Maintenance The LED source has an expected life of 50,000 hours, more than 13 years at 10 hours on per night. No maintenance is required on the LED array, and lamp replacements on the incandescent portion will be extended considerably. The motion sensor portion of the fixture uses conventional motion senor technology, which has been in use in the industry for many years.
Performance Verification	This product is produced as a complete integrated solution. It is the recommendation that individual, component solutions not be encompassed by the revised table in section 147. If someone were to provide a component solution consisting of a motion sensor, separate LED array and conventional luminaire, there would be significant site verification and commissioning issues that would arise. Given that this product is a turnkey solution which does not require any calibration of the motion sensor, simple field verification of the installation would suffice.
Cost Effectiveness	The cost effectiveness of this fixture depends high on the amount of time the outdoor light is going to be on. However, it can be expected that in applications that require lighting all nigh, paybacks of less than five years can be expected.
Analysis Tools	This measure would not be subject to the whole building performance method. Simple calculations based upon usage patterns have been done to show the energy savings potential.
Relationship to Other Measures	Potentially, this measure could result in more low-efficacy lighting use in outdoor applications. However, the mandatory measures in the standards do permit the low efficacy uses in conjunction with motion sensors, so this technology fits well with that requirement.

Methodology

The 2005 Title 24 requires that outdoor lighting in nonresidential applications be tabulated and show compliance with a certain watt per square foot allowance. Unlike indoor lighting, however, there are no credits given for lighting controls on outdoor fixtures. While certain controls are mandatory, such as a photosensor or astronomical time clock, and in some cases multi-level switching, no credit is given to occupancy sensor based control. Based upon the outcome of the PIER study with 87% savings shown, it would be recommended that we apply a 50% lighting Power Adjustment Factor (PAF) for the use of this technology. While 87% may seem like the logical choice, it has always been past policy to reduce the control credits to account for user override, and non-operational controls. To illustrate an example, we might have two possible scenarios:

1. CFL Based design with lighting always on:
   10 lamps @ 15 watts = 150 watts.
   12 hrs operation X 365 days x 150 watts = 657 kWh/yr

2. LED / Incandescent hybrid based design:
   10 lamps @ 60 watts = 600 watts.
   10 lamps @ 5 watts = 50 watts. Adjusted by 0.50 PAF = 325 watts
   12 hrs operation x 365 days x 600 watts x 13% = 342 kWh/yr.

Analysis and Results

The CLTC research team generated ten luminaire concepts and developed four prototypes. The team then successfully built two pre-production prototypes—a Hybrid LED fixture and a PAR security light. The hybrid fixture is commercially available from Shaper Lighting.

Using LEDs together with occupancy sensors is an excellent application for outdoor lighting. This combination provides low-level ambient lighting all night long, switching to full light level only when needed. The LEDs use only about 0.06 kWh per night, costing less than $0.01 per night. Because of the low usage, incandescent lamps are more cost effective than compact fluorescent for full light level, with the marginal payback for the CFLs at about 10 years. Not only do CFLs have a long marginal payback because of such low usage, but intermittent use of CFLs is not a good application because their warm-up time causes dim conditions and reduces user satisfaction for the very short illumination need.

Recommendations

It is recommended that a new table be added to section 147 of the standards.

Table 147-D LIGHTING POWER ADJUSTMENT FACTORS

TYPE OF CONTROL	TYPE OF APPLICATION	FACTOR
Occupant sensor controlled	Pedestrian Hardscape	0.50

primary light source with secondary
“Always-On” LED light source
integrated with photosensor.

Additional language in Section 147 would include:

(b) Calculation of Actual Lighting Power. The actual lighting power of outdoor lighting is the total watts of all lighting systems (including ballast or transformer loss).

1. Reduction of wattage through controls. The controlled watts of any luminaire may be reduced by the number of controlled watts times the applicable factor from TABLE 147-D if:

   A. The control complies with Section 119; and
   B. At least 50 percent of the light output of the luminaire is within the applicable application listed in TABLE 147-D; and
   C. Except as noted in TABLE 147-D, only one power adjustment factor is used for the luminaire.

In the mandatory measures section 132 of the standards, under the controls for outdoor lighting, the following additional exceptions would be added to exempt this type of lighting from the 50% switching requirement.

EXCEPTIONS to Section 132 (c) 2:
1. Lighting required by a health or life safety statute, ordinance, or regulation, including but not limited to, emergency lighting.
2. Lighting for steps or stairs that require illumination during daylight hours.
3. Lighting that is controlled by a motion sensor and photocontrol.
4. Lighting for facilities that have equal lighting requirements at all hours and are designed to operate continuously.
5. Temporary outdoor lighting.
6. Internally illuminated, externally illuminated, and unfiltered signs.
7. <u>Lighting that is controlled by an motion sensor and photocontrol that includes a secondary “Always-ON” LED light source, provided the LED light source is less than 10 watts.</u>

Material for Compliance Manuals

Chapter 8 changes to the Nonresidential Manual are listed below.

Installed Power

§130 (c)

The installed power for outdoor lighting applications shall be determined in accordance with §130 (c). Luminaire power for pin-based and high intensity discharge lighting system types that are listed in ACM Manual Appendix NB may be used as an alternative to determine the wattage of outdoor luminaires. However, luminaires with screw-base sockets, and lighting systems which allow the addition or relocation of luminaires without altering the wiring of the system must be determined in accordance with §130 (c). Please see Chapter 5.4.3 of the Nonresidential Manual, Determining Luminaire Wattage, for additional discussion on installed power~~. Unlike indoor lighting, no power credits are offered for automatic controls~~. ***Actual lighting power (adjusted)*** is based on total design wattage of lighting, less adjustments for any qualifying automatic lighting controls. ~~However,~~ Some automatic controls are required by the mandatory measures.

1.7 Automatic Lighting Control Credits

§147(b)1

The controlled watts of connected lighting outside the building may be adjusted to take credit for the benefits of certain types of automatic lighting controls. A list of the controls that qualify for these credits is shown in Table147-D in the Standards.

The lighting control credits set out "Power Adjustment Factors." These are multipliers that allow the actual lighting power to be reduced, giving a lower adjusted lighting power. This makes it easier to meet the allowed lighting power requirement. A credit is only permitted when the control types indicated in Table147-D are used.

In order to qualify for the power savings adjustment, the control system or device must be certified (see Section 5.2.1 **Error! Reference source not found.**), and must control all of the fixtures for which credit is claimed; only controlled luminaires are eligible for lighting control credit.

Table 6-7 – Standards Table 147-D Lighting Power Adjustment Factors

TYPE OF CONTROL	TYPE OF APPLICATION	FACTOR
Occupant sensor controlled primary light source with secondary "Always-On" LED light source integrated with photosensor.	Pedestrian Hardscape	0.50

OLTG-5-C: Lighting Controls Credit Worksheet

1. OLTG-5-C is used to report the control credits for outdoor applications. When certain types of automatic lighting controls listed in Table 147-D in the Standards are used, a credit is permitted. This table also lists some restrictions that must be met in order to take credit for the controls.
   - Lighting control credits are documented on form OLTG-5-C. This requires a specific listing of each device that is used for credit and listing those luminaires controlled by that device.
   - APPLICATION – List the area where the control device is controlling luminaires.
   - DESCRIPTION – List a description of that device.
   - PLANS – Indicate where on the plan set the controls are shown.

2. WATTS OF CONTROL LIGHTING – The total watts of controlled lighting in each application.
3. POWER ADJUSTMENT FACTOR – Indicate the power adjustment factor for that specific control device from Table 147-D in the Standards.

4. CONTROL CREDIT – The product of COLUMN G (Watts of Control Lighting) and COLUMN H (Power Adjustment Factor).
5. The total control credit watts (entered on OLTG-5-C) is the sum of the control credit watts in COLUMN J. This credit is subtracted from the total installed watts to determine the actual lighting power (adjusted).

Bibliography and Other Research

Information for this measure template has been taken from the PIER research project number 500-01-041-A2 report. This PIER report is available from the California Energy Commission's PIER group as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

The hyperlink for this project is as follows:

http://www.archenergy.com/lrp/lightingperf_standards/project_5_3.htm

Communications related to this template

-----Original Message-----
From: Don Aumann [mailto:daumann@ucdavis.edu]
Sent: Monday, April 24, 2006 10:25 AM
To: 'Michael Seaman'; kfj4@hotmail.com; 'Karl Johnson'
Cc: mart@energysoft.com
Subject: RE: LED Hybrid Fixture

Here's some info that should help:

NPS DEMO
Site: Death Valley National Park
Test Units: ~20 Shaper
~30 Hunter
Installation: May and June, 2006
Applications: residential and commercial entry way (~35-40 units)
1 or 2 pathways (~6-12 Shaper units)

LRP FINAL PHASE

- We working with Hunter to develop a unit with lower cost than the Shaper product
- Hunter built 150 pre-production units in China which used an updated WattStopper controller (compared to the Shaper unit) but it had a small glitch so CLTC is working to address this
- WattStopper needs to redesign some circuitry in the controller for a long-term solution; this is a pending activity
- We are not promoting the Shaper units because Shaper isn't promoting them, although I've heard they're still nominally in the catalogue

COMMERCIAL VS. RESIDENTIAL APPLICATION

- Either market sector is viable for this technology; I'd guess the primary issue to be the product "look" or packaging for appropriate markets
- The UC PIER demonstrations will be on small campus buildings at UC Davis, effectively a commercial application
- The NPS demo will include doors/entries on a visitor center, as well as a visitor center walkway… both are commercial applications (they're also doing residential applications)
- SMUD conducted a demo on a multi-family building… quasi commercial, quasi residential

I'll let Karl pass on more UC/CSU details. Let me know if you need more info.

Don

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- - - -

-Original Message-----
From: Karl Johnson [mailto:kfj4@hotmail.com]
Sent: Monday, April 24, 2006 11:29 AM
To: daumann@ucdavis.edu; Mseaman@energy.state.ca.us; karl.johnson@ucop.edu
Cc: mart@energysoft.com
Subject: RE: LED Hybrid Fixture

Hi Michael and Don,

I will build on Don’s response as follows:

We are testing several hybrid technologies in the UC/CSU demo. Two are for bathrooms; a bathroom smart switch with an LED nightlight and the smart bathroom fixture with the LED nightlight. See attached draft case study describing these demonstrations at UC Davis and CSU Sanoma State.

We are also demonstrating two versions of the exterior Hybrid entrance fixture, one by Shaper and the other by Hunter. These will be at UC Davis as Don noted and maybe another campus.

That’s the short version – if you need more details let me know, Karl

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Hotel/Dormitory Bathroom Lighting Control Systems

"We are so pleased with these bathroom technologies that we are planning to retrofit more dorms very soon!"
Lance Veit—Project Manager, Student Housing, UC Davis

PIER Buildings Program ***Research Powers the Future*** ***www.energy.ca.gov/pier***

Energy Savings Opportunity

Fixture or switch with LED nightlights, sensors, big savings

Bathroom lights generally operate between five to eight hours per day in dormitories and six to twelve hours per day in hotels. Guests either leave the light on as a nightlight or simply forget to shut the lights off when they leave the bathroom. Not only does this waste electricity, it also means maintenance must replace the lamps more often.

To address these issues, California Lighting Technology Center (CLTC) researchers partnered with MetalOptics (an Acuity brand) and Watt Stopper to develop a bathroom-specific luminaire that integrates a low-wattage light emitting diode (LED) nightlight and a vacancy sensor that saves energy while improving occupant satisfaction. As a complete bathroom lighting package, it includes an emergency battery backup for the LED nightlight array. CLTC researchers also partnered with Watt Stopper on a separate project to develop a wall switch that performs the same task using an existing fixture. While LEDs and motion sensors are not new, these companies have integrated them into innovative systems which save electricity and decrease maintenance costs.

Bathroom fixture (MetalOptics) and wall switch (Watt Stopper).

Product Overview

Energy Savings
Reduces lamp use during unoccupied and sleeping periods by 30% to 50%

Operation/Maintenance:
Increased lamp life, cuts O&M by 33%, fewer lamp outage complaints

Manufacturer:
MetalOptics; Watt Stopper

Market:
Hotel, dormitory, and assisted living bathrooms.

Availability:
The MBV fluorescent bathroom vanity wall mount is currently available by special order from MetalOptics. www.metaloptics.com
The WN-100 Bathroom Switch is currently available from Watt Stopper. www.wattstopper.com

Public Interest Energy Research ***University of California*** ***California State University***

Field Demonstration
UC Davis and Sonoma State

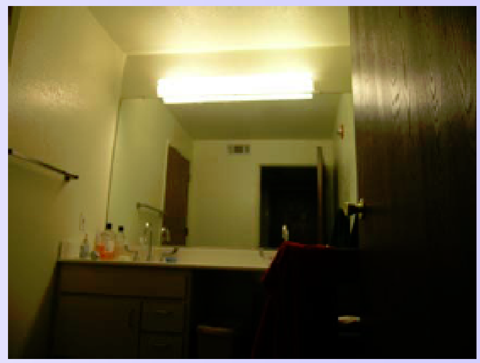
Webster Dormitory at UC Davis is a suite style freshman living facility with 2 bathrooms per unit. By summer 2006, all 200 bathrooms will have been retrofitted with the new bathroom fixture/wall switch. Beaujolais Hall at Sonoma State Univ. will have 50 dormitory rooms retro-fitted with the new bathroom fixture in summer 2006.

Lessons Learned:

- Short learning curve for installation electricians
- Original vacancy sensor time delay was one hour. After reducing the time delay to fifteen minutes, savings noticeably increased. Users did not notice the adjustment.
- Switches/fixtures in bathrooms that directly join bedrooms are left on less than those in bathrooms that are separate.
- Wall switch is best suited for smaller bathrooms due to light output of LED.

CPUC Partnership

The University of California/California State University (UC/CSU) and Investor-Owned Utility (IOU) Partnership Program has identified incentives for this technology from $10 to $30 per fixture. For more information please visit: www.uccsuiouee.org.



Top: Original 4-foot T-12 bathroom vanity fixture
Bottom: New MBV vanity wall mount with LED nightlight.

Installation Costs

Retrofit:

Once the installation electrician is familiar with the wiring diagram provided by the manufacturer, the time per fixture dropped from one hour to 45 minutes. The labor noted in the table includes disposal of the old fixture. Wall switch cost was $35 per unit and the new fixtures were $175 each.

New Construction/Renovation:

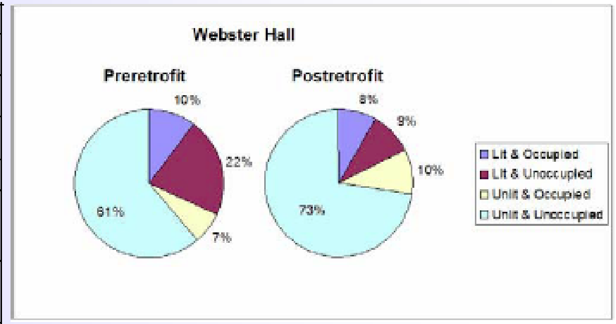
For new construction or renovation applications, the labor is included in the cost already allocated to the project so this does not enter into the payback calculation. Material price for the MBV fixture is more than a standard fluorescent vanity wall mounted fixture due to the added sensor, controller, and LED array. The same is true of the WN-100 wall switch.

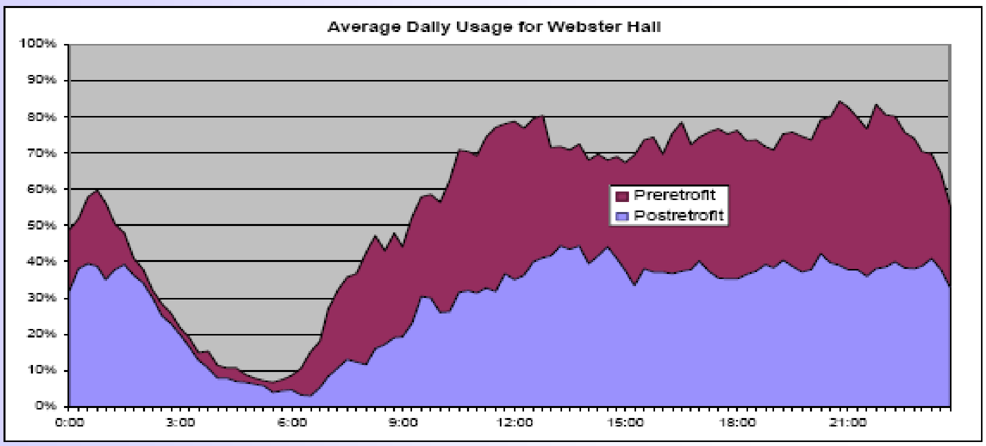
Payback (for UC/CSU campuses with CPUC Incentives)

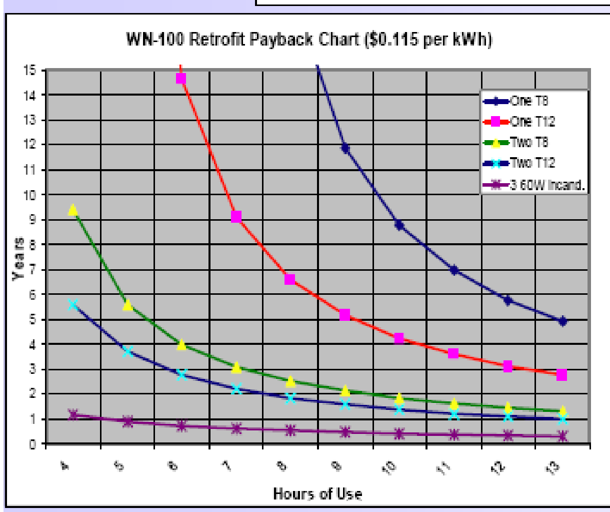
		WN-100 Wall Switch			MBV Fixture		
Application	Operation	Material (Avg.)	Labor (Avg.)	Payback ($0.115 per kWh)	Material (Avg.)	Labor (Avg.)	Payback ($0.115 per kWh)
Hotel Retrofit	3,900 hr/yr	$10	$15	0.5-3 years	$145	$55	3-10 years
Dormitory Retrofit	2,100 hr/yr			2-5 years			4-11 years
Hotel New/Renovation	3,900 hr/yr	$5	$0 (incl.)	~ 0.4 years	$70	$0 (incl.)	~ 1.9 years
Dormitory New/Renovation	2,100 hr/yr			~0.7 years			~ 3 years

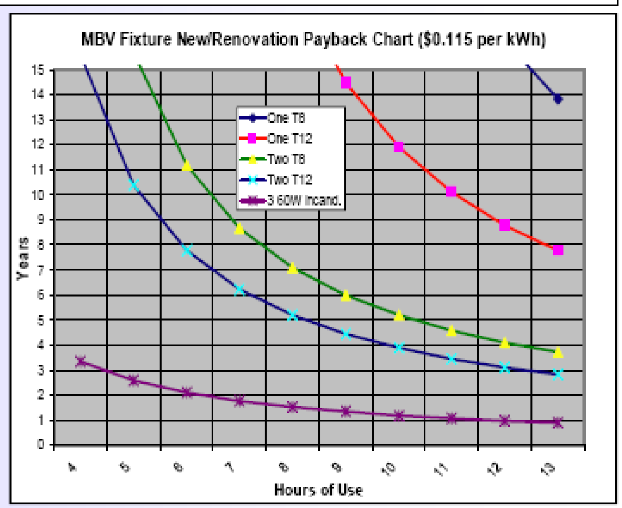
Study Results

Pre-retrofit	
Fixture Type	One lamp T-12, white lens
Wattage (avg.)	42.5 W w/ electronic ballast
Usage (300 days/yr)	Average of 7.5 hr/day
Post-retrofit	
Fixture Type	MBV one lamp T-8, white lens; WN-100 Switch with old fixture
Wattage (avg.)	MBV: 34 W w/ electronic ballast; WN-100: 43.5 W w/ LEDs
Usage (300 days/yr)	Average of 4.7 hr/day
Bldg. Energy Savings	Approx. 8,000 kWh/yr
Annual Savings	Approx. $1,000 per year









Payback nomographs, without CPUC incentives, for bathroom lighting technologies.

WN-100 wall switch in Webster Dormitory bathroom

Considerations

Ease of Installation:
Fixture installations generally took less than an hour. Once an electrician is familiar with wiring instructions, the installation time per fixture drops. Installation time for each of the wall switches was ten minutes or less.

Attractiveness:
Students reported much better light quality and less eye fatigue with the new fixtures. Those who used the MBV or the WN-100 found the LED feature more pleasant than turning on the fixture in the middle of the night.

Issues/Concerns:
None

Conclusion

Cost Effectiveness:
The fixture is most cost effective when used in new construction and renovation projects. The wall switch is best for retrofit applications given its relatively low unit price. Though the fixture has a longer payback, its LED array produces less glare and is a better nightlight than that used in the wall switch.

Potential Impact:
Potential for significant energy savings, lower maintenance costs, increased user satisfaction.

Applicability:
Both the fixture and switch are useful in hotel, dormitory, and assisted living facilities.

Considerations:
Installation of either the switch and fixture is relatively easy. Both offer significant energy savings and an attractive nightlight feature. Fixture offers improved light quality over most fluorescent vanity fixtures and the switch produces rapid paybacks in retrofit applications.

Availability

The MBV fluorescent bathroom vanity wall mount is currently available through MetalOptics at approximately $175 for the four-foot version. Other sizes and diffuser options are also available. The bathroom wall switch, WN-100, is currently available from Watt Stopper at approximately $35 per unit depending on order size. This also comes with various color options for the faceplate and LEDs.

About PIER

This project was conducted by the California Energy Commission's Public Interest Energy Research (PIER) program. PIER supports public-interest energy research and development that helps improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

For more information see www.energy.ca.gov/pier

Arnold Schwarzenegger, ***Governor***
California Energy Commission
Chairman: Joseph Desmond *Vice Chair:* Jackalyne Pfannenstiel
Commissioners: Arthur H. Rosenfeld, James D. Boyd, John L. Geesman

1.26.2006
Pub # 0000

Load Shedding Ballasts

2008 California Building Energy Efficiency Standards

PIER Program - EnergySoft, LLC January 05, 2006

Overview

Complete the following table, providing a brief sentence or two for each category of information.

Description	The load-shedding ballast enables lighting to be a cost-effective tool for electrical demand response. Building on the highly successful instant-start ballast platform, the load-shedding ballast is designed to keep costs low while maintaining the highest available energy efficiency among competing ballast types. The load-shedding ballast combines technology for dimming instant-start operated fluorescent lamps with a means of remote signaling that allows all such ballasts in an area to reduce power by 33% upon command. The ballast is signaled via a power line carrier so no additional wiring is required. The load shedding ballast must have a ballast efficacy factor (BEF) of equal to or greater than 1.48.
Type of Change	This change is proposed to be an addendum to Table 146-A, the Prescriptive Lighting Power Adjustment Factor table. It is proposed to add an additional entry in this table providing credit for use of this technology.
Energy Benefits	Lighting is a major electric load (20% of peak electric loads in commercial buildings) that can be dimmed without affecting worker productivity. The widespread use of the load-shedding ballast in the new building construction, remodeling, and replacement market can produce reductions in peak electric demands in California of 100 megawatts.
Non-Energy Benefits	There are no non-energy benefits that can be attributed to this product, other than the potential for reduced utility costs as part of participation in a utilities demand response program.
Environmental Impact	This product is merely an enhancement to existing ballast technology so it does not present any environmental impacts.

Technology Measures	Measure Availability and Cost The estimated incremental cost of this technology is $9.00 per ballast. The Lighting Research Center has been able to partner with a large ballast manufacturer to commercialize the load-shedding ballast, although there are no certain plans for commercialization of the product. Useful Life, Persistence and Maintenance This product will have a useful life equivalent to the ballast life. In addition, from lamp life experiments, power reductions of 33% for periods of time when load shedding is needed were shown to have virtually no effect on lamp life.
Performance Verification	Currently, the certificate of acceptance is used to verify correct installation and implementation of lighting controls. It is recommended that this same acceptance from be used for the load shedding ballasts.
Cost Effectiveness	Two economic analyses were conducted to determine the return on investment to the customer and the total resource cost test for California ratepayers. It was determined that a $9.00 incremental cost over that of a standard instant start ballast would give the customer a payback of approximately three years. Because, under the scenario that the ballast is being installed as part of new construction or remodeling or for other reasons such as energy efficiency, there is no added installation cost when installing a load-shedding ballast.
Analysis Tools	It is anticipated that the load shedding ballast be treated in a similar fashion to the load shedding dimming systems that are incorporated into Table 146-A.
Relationship to Other Measures	This measure does not impact other measures.

Methodology

The 2005 code includes a Power Adjustment Factor (PAF) credit in table 146-A for the use of dimming electronic ballasts combined with automatic load control. The load shedding ballast promoted in this report is a similar parallel to that technology. Although it does not dim the fixtures, it does achieve the load shedding intent of the technology. Clearly the current credit achieves energy savings not only from the load shedding, but also from dimming that will occur with occupant control at non-peak hours of the day. It would make sense to add an entry into table 146-A which would apply a credit for this technology.

Dimmers alone in this table achieve a 10% PAF, and the load shedding with dimmers achieves a 25% PAF, so it would make sense that the load shedding alone should achieve a 15% PAF as a separate line item in this table.

Note that the load shedding ballast will consume less than 0.5 watts of additional energy on the ballast, and that this will be accounted for in the final LPD calculations. However, it may be prudent to include language that will limit the additional energy usage of the product to prevent using more energy at the sake of reducing demand.

Also note that in the 2008 Standards both the dimming electronic ballast and the load shedding ballasts must have a BEF of 1.48 or greater.

Analysis and Results

This analysis examines the customer cost savings if the load-shedding ballast technology were applied compared to the incremental cost of the ballast or retrofit device installed as part of a new construction/renovation project or retrofitted into existing buildings. The savings are expressed on per light fixture/ballast basis. Firm, interruptible and load management rates of Southern California Edison (SCE), Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), Sacramento Municipal Utility District (SMUD) and Los Angeles Department of Water and Power (LADWP) were used to determine customer cost savings.

The customer cost for the retrofit device is estimated to be $9 and the load-shedding ballast has an incremental cost of $9 over an instant start ballast. These prices include the sharing of the cost for the signaling device. The installation cost of the retrofit device or the load-shedding ballast into an existing light fixture is estimated to be $10 per fixture. There is no incremental installation cost for new light fixture with the load-shedding ballast installed and used in new construction or as part a building's renovation.

Action	Rate	Annual Savings per Device
SCE		
Monthly Peak Demand Reduction	TOU-8	$3.48
Interruptible Rate	I-6-BIP	$2.52
Critical Peak Pricing Rate	TOU-8-CPP	pricing not available
PG&E		
Monthly Peak Demand Reduction	E-20S	$3.06
Interruptible Rate	E-BIP	$2.52
Demand Bidding	E-DBP	$1.05
Load Reduction	E-SLRP	$0.30
Critical Peak Pricing Rate	E-CPP	$3.96
SDG&E		
Monthly Peak Demand Reduction	AL-TOU	$3.08
Interruptible Rate	BIP	$2.52
Demand Bidding	DBP	$1.05
Load Reduction	SLRP	$0.30
Critical Peak Pricing Rate		pricing not available
SMUD		
Monthly Peak Demand Reduction	GS-TOU1	$1.51
Load Reduction	PowerNet	$0.75

Recommendations

The change to Table 146-A is included below.

TYPE OF CONTROL	TYPE OF SPACE	FACTOR
Automatic load control of load shedding ballasts With a BEF of 1,48 or greater.	All Space	0.15

Material for Compliance Manuals

Changes to the Nonresidential Manual are included below:

Other Control Credits

Table 146-A of the Standards also provides control credits for the following technologies and spaces:

- Occupant sensor controlled multi-level switches or dimming systems that reduce the lighting power at least 50% in hallways of hotel/motels, commercial and industrial storage stack areas (maximum two aisles per sensor), and library stacks (maximum two aisles per sensor). This can be accomplished by placing half of the lighting in these areas on an occupancy sensor and the remainder on a manual switch. Only the fraction of the lighting that is on the occupancy sensor qualifies for the credit (§146(a)4 "controlled watts of any luminaire…").
- Dimming systems including manual and multi-scene programmable systems in hotels/motels, restaurants, auditoriums, and theaters.
- Manual dimming with automatic load control of dimmable electronic ballasts, with a BEF of 1.48 or greater, in all building types. This control system allows load shedding (dimming lights) initiated by the utilities or other grid system operators in the event of an electricity shortage. To qualify for this credit the dimming system in the building must have a control system that is ready to respond to a load curtailment or real time pricing signal. Such a system is enabled to dim all lights receiving the control credit below a fixed setting or to a fraction of their setting at the time the signal is received.
- Automatic load control of load-shedding ballasts, with a BEF of 1.48 or greater, in all building types. This control system allows load shedding (dimming lights) initiated by the utilities or other grid system operators in the event of an electricity shortage. To qualify for this credit the building must have a control system that is ready to respond to a load curtailment or real time pricing signal. Such a system is enabled to dim all lights receiving the control credit. In addition, each light that qualifies for this credit must be equipped with a load shedding ballast that will respond to the signal to dim the lights, and provide a minimum 30% reduction in lighting input power upon receiving the signal.

Table -1 – Standards Table 146-A Lighting Power Adjustment Factors

TYPE OF CONTROL	TYPE OF SPACE		FACTOR
Occupant sensor with "manual ON" or bi-level automatic ON combined with multi-level circuitry and switching	Any space ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, corridor, conference or waiting room		0.20
Occupant sensor controlled multi-level switching or dimming system that reduces lighting power at least 50% when no persons are present	Hallways of hotels/motels		0.25
	Commercial and Industrial Storage stack areas (max. 2 aisles per sensor)		0.15
	Library Stacks (maximum 2 aisles per sensor)		0.15
Dimming system			
Manual	Hotels/motels, restaurants, auditoriums, theaters		0.10
Multiscene programmable	Hotels/motels, restaurants, auditoriums, theaters		0.20
Manual dimming with automatic load control of dimmable electronic ballasts with a BEF of 1.48 or greater.	All building types		0.25
A automatic load control of load-shedding ballasts with a BEF of 1.48 or greater..	All building types		0.15
Combined controls			
Occupant sensor With "manual ON" or bi-level automatic ON combined with multi-level circuitry and switching in conjunction with daylighting controls	Any space ≤ 250 square feet within a daylit area and enclosed by floor-to-ceiling partitions, any size classroom, corridor, conference or waiting room.		0.10 (may be added to daylighting control credit)
Manual Dimming with Dimmable Electronic Ballasts and Occupant sensor with "manual ON" or automatic ON to less than 50% power and switching	Any space ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, corridor, conference or waiting room		0.25
Automatic Daylighting Controls with Windows (Stepped Switching or Stepped Dimming/Continuous Dimmed) (Numbers on the left side of a slash apply to Stepped Switching or Stepped Dimming. Numbers on the right side of a slash apply to Continuous Dimming)			
	WINDOWS – Window Wall Ratio		
Glazing Type	< 20%	20% to 40%	> 40%
VLT ≥ 60%q	0.20/0.30	0.30/0.40	0.40/0.40
VLT ≥ 35 and < 60%	0/0	0.20/0.30	0.30/0.40
VLT < 35%	0/0	0/0	0.20/0.40
Automatic Multi-Level Daylighting Controls with Skylights			
Glazing Type - Skylights	Factor		
Glazing material or diffuser with ASTM D1003 haze measurement greater than 90%	$10 \times \text{Effective Aperture} - \frac{\text{Lighting Power Density}}{10} + 0.2$ WHERE Effective Aperture is as calculated in the Equation 146-A. Lighting Power Density is the lighting power density of general lighting		

Bibliography and Other Research

Information for this measure template has been taken from the PIER research project number 500-01-041-A6 report. This PIER report is available from the California Energy Commission's PIER group as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

The hyperlink for this project is as follows:

http://www.archenergy.com/lrp/demandresp_lighting/project_3_2_reports.htm

Advanced Daylighting Control System for Classrooms

2008 California Building Energy Efficiency Standards

PIER Program - EnergySoft, LLC

January 05, 2006

Overview

Complete the following table, providing a brief sentence or two for each category of information.

Description	Describe the proposed measure or change and how it would apply to buildings regulated by the California Building Energy Efficiency Standards. Describe the building types or systems where the change/measure would most likely apply. Provide appropriate details. Keep the description brief – just a single paragraph, if possible.

Type of Change

Describe how the measure or change would be addressed in the California Building Energy Efficiency Standards, e.g., is the proposed change likely to be a mandatory measure, prescriptive requirement, or compliance option? Would it change the way that trade-off calculations are made? The following describes the types of changes in more detail:

Mandatory Measure	The change would add or modify a mandatory measure. (Mandatory measures must be satisfied whether the prescriptive or performance method is used to show compliance.)
Prescriptive Requirement	The change would add or modify a prescriptive requirement. Prescriptive requirements must be met when using prescriptive compliance. When using performance compliance (computer modeling), prescriptive requirements define a standard design (which sets the energy budget) and are not mandatory.
Compliance Option	The change would add or modify a new measure to the list of existing compliance options for meeting the Standards using the performance approach.
Modeling	The change would modify the calculation procedures or assumptions used in making performance calculations. This change would not add a compliance option or a new requirement, but would affect the way that trade-offs are made.
Other	If the proposed change is not a mandatory or prescriptive requirement, compliance option or modeling assumption or change, please describe what type of change it is.

Does the proposed change modify or expand the scope of the Standards? As a result of the change, would the Standards address new issues or provide requirements for systems or equipment, not previously regulated?

Identify the Standards documents (Standards, ACM, Manuals, compliance forms, etc.) that would need to be modified in order to implement the proposed change. Briefly describe the nature of the change to each document.

Energy Benefits

Describe the benefits of the change/measure, especially energy savings and electricity peak demand reduction. Describe how Time Dependent Valuation (TDV) would affect benefits attributed to the measure. Reference the "Analysis and Results" section below for detailed calculations.

Non-Energy Benefits

Identify non-energy benefits, such as comfort, reduced maintenance costs, environmental benefits, improved indoor air quality, health and safety benefits, productivity, and/or increased property valuation.

Environmental Impact	Does the change/measure have any potential adverse environmental impacts? Is water consumption increased? Does it have an impact on indoor air quality or otherwise affect indoor environmental quality? Does it affect atmospheric emissions (including ozone depleting gases)? Are there environmental or energy impacts associated with material extraction, manufacture, packaging, shipping to the job site, installation at the job site, or other activities associated with implementing the measure in buildings?
Technology Measures	If the measure requires or encourages a particular technology, address the following, otherwise skip this section.

Measure Availability and Cost: Identify the principal manufacturers/suppliers who make the measure (product, technology, design strategy or installation technique), and their methods of distribution. Is the measure readily available from multiple providers? Comment on the current ability of the market to supply the measure in response to the possible Standards change and the potential for the market to ramp up to meet demand associated with the possible Standards change. Identify competing products.

Useful Life, Persistence and Maintenance: Describe the life, frequency of replacement, and maintenance procedures related to the measure. How long will energy savings related to the measure persist? Is persistence related to performance verification, proper maintenance and/or commissioning? If there are issues related to persistence, how can they be addressed? (See Performance Verification below.)

Performance Verification	In this section, identify the type of performance verification or commissioning that is needed in order to assure optimum performance of the measure. For residential buildings, field verification and diagnostic testing are required for many measures. For nonresidential buildings, the parallel is acceptance testing. Here are some questions to ask: Does the technology or design strategy need performance verification or commissioning to insure that it is properly installed and/or performing as designed? How are energy performance, useful life and persistence of savings affected by performance verification or commissioning? What specific performance verification measures or requirements are needed to assure that the measure is properly installed and performing as designed?

Cost Effectiveness	Is the proposed change likely to be cost effective? If the change is a mandatory measure or prescriptive requirement, then it is necessary to demonstrate cost effectiveness. See the "Methodology" and "Analysis and Results" sections below, and present the detailed analysis there. While cost effectiveness justification is not needed for compliance options, it will help make the case for their consideration.
Analysis Tools	What tools would be needed to quantify energy savings and peak electricity demand reductions? Can these benefits be quantified using the current reference method? What enhancements to the reference method are needed, if any? If a measure is proposed as mandatory, then analysis tools are not relevant, since that measure would not be subject to whole building performance trade-offs.
Relationship to Other Measures	Identify any other measures that are impacted by this change. Explain the nature of the relationship.

Methodology

Describe the methodology and approach used to develop the recommendations for the measure. Typically this section will contain the assumptions used for the analysis of the measure, a description of the base case (current Standards or current practice) and the proposed Standards case.

The content of this and the following section will depend on the type of measure proposed.

- For any measure proposed as mandatory or prescriptive, perform life-cycle cost analysis s to demonstrate that the measure is cost effective. The procedures for calculating life-cycle cost effectiveness are documented in *Life-Cycle Cost Methodology, 2008 California Building Energy Efficiency Standards* (available soon). Discuss the measure's cost effectiveness.
- For measures proposed as compliance options, life-cycle cost analysis is generally not necessary, since the measure is not proposed to be part of the baseline level of Standards stringency. However, cost justification may improve the chances of the measure being approved. In this case, this section may explain how the measure is to be modeled with the reference method.
- If the measure is a modeling change, this section may deal with the process of how the modeling assumption and/or algorithm affects trade-offs and accuracy of trade-offs.

Analysis and Results

Describe the results of the research. What was learned? How is it relevant to the Standards? Results are not all computational. Some results are based on market share of equipment and applicability of measure limited to certain applications. Provide the following information as applicable:

- *Energy and Cost Savings.* Document the energy and cost savings results that are summarized in the overview section of the report.
- *Cost-effectiveness.* Document the cost effectiveness of the measure following the Energy Commission methodology referenced earlier.
- *Modeling Rules or Algorithms.* Explain the recommended modeling rule or algorithm, how it was developed and how it improves the Standards.

Recommendations

Summarize the specific recommendations for changing the Standards and/or the ACM Manuals. This section should have specific recommended language and contain enough detail to develop the draft standard in the next phase of work. Use the language from the relevant 2005 document(s), and use underlining to indicate new language and strikethroughs to show deleted language.

Material for Compliance Manuals

In this section of the research report, provide information that will be needed to develop the Residential and/or Nonresidential Compliance Manuals, including:

- Possible new compliance forms or changes to existing compliance forms.
- Examples of how the proposed Standards change applies to both common and outlying situations. Use the question and answer format used in the 2005 Residential and Nonresidential Compliance Manuals.
- Any explanatory text that should be included in the Manual.
- Any data tables needed to implement the measure.

The goal is for the author of the evaluation report to provide materials that can later be incorporated into the Nonresidential or Residential Compliance Manual. Requiring that the author/researcher think about compliance and enforcement issues will result in an improved recommendation, one that is less ambiguous and more workable.

Bibliography and Other Research

Information for this measure template has been taken from the PIER research project number 500-01-041-A8 report. This PIER report is available from the California Energy Commission's PIER group as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

The hyperlink for this project is as follows:

http://www.archenergy.com/lrp/advlight_luminaires/project_4_5.htm

LED Night Lighting in Bathrooms

2008 California Building Energy Efficiency Standards

PIER Program - EnergySoft, LLC

January 05, 2006

Overview

Description	The California Lighting Technology Center (CLTC) research team developed two energy efficient bathroom lighting technologies that will save energy and improve safety in hotel bathrooms and related institutional applications. The first is a Motion Sensor Nightlight, targeted at retrofit applications. It is now a commercial product produced and distributed by The Watt Stopper as product WN-100. The second is a "Smart" Light Fixture (SLF), targeted at new construction or major renovations, to be produced and distributed by Speclight, a subsidiary of Lithonia Lighting. Both products reduce bathroom lighting energy use by about 50 to 75 percent.
Type of Change	The recommended language change would be to the Mandatory Measures section of 150 in the Standards. Currently, the Standards would not permit the use of this type of technology, since the LED does not meet the minimum efficacy requirements and therefore must be controlled by a motion sensor. This would defeat the purpose of the LED.
Energy Benefits	A field study of the product at the Sacramento Doubletree hotel demonstrated an average of 50% energy savings.
Non-Energy Benefits	This product provides an additional level of safety in bathroom applications because of the always on function. In addition, the LED feature can be tied into hotel emergency lighting systems to provide an additional measure of safety in power outages.
Environmental Impact	There is no significant environmental impact with the use of the LED technology.
Technology Measures	Measure Availability and Cost Both products described here are now available from at least one manufacturer. This measure template proposal simply proposes a slight change in language which would permit the use of this technology, thus prompting more widespread use by other manufacturers. Useful Life, Persistence and Maintenance The LED technology has a much longer life than the fluorescent light in theses products. In addition, the product does not require any maintenance.

Performance Verification	There is no additional performance verification required with the use of this product.
Cost Effectiveness	The payback on this measure is 2-5 years when used in hotel room applications. It will probably be longer in conventional residential applications.
Analysis Tools	No energy savings claims are being requested for this technology.
Relationship to Other Measures	The residential standards also include a table for minimum efficacy requirements for high efficacy light fixtures.

Methodology

While the tests done with technology demonstrate a 2-5 year payback, based upon field measured energy savings, this proposal does not seek any credit in the Standards for the use of this technology. The purpose of this proposal is merely to permit the use of the technology, which has demonstrated energy savings over conventional bathroom lighting, through a slight change in the mandatory measures section.

Analysis and Results

This project has successfully met its objective in developing lighting technologies that save 50 to 70 percent of the lighting energy used in hotel and institutional bathroom applications. The project goals and scope have been exceeded with two technologies resulting in commercial products produced and distributed by the manufacturing partners of the project: a Motion Sensor Nightlight (WN-100) manufactured and distributed by The WattStopper and a “Smart” Lighting Fixture (SLF) manufactured and distributed by Speclight. The WN-100 was installed at the Sacramento Doubletree Hotel and resulted in 50% average savings. The SLF is currently in preparation for production. Several demonstration applications are being planned in hotel, dormitory, and assisted living facilities.

Recommendations

Summarize the specific recommendations for changing the Standards and/or the ACM Manuals. This section should have specific recommended language and contain enough detail to develop the draft standard in the next phase of work. Use the language from the relevant 2005 document(s), and use underlining to indicate new language and strikethroughs to show deleted language.

Material for Compliance Manuals

It is recommended that Table 150-C of the Standards as well as the table in section 2.17 in the Nonresidential Manual include an additional line item for lamps less than 5 watts, allowing 30 lumens per watt.

Table -2 – Standards Table 150-C

Lamp Power Rating	Minimum Lamp Efficacy
5 watts or less	30 lumens per watt
Over 5 watts to 15 watts	40 lumens per watt
Over 15 watts to 40 watts	50 lumens per watt
Over 40 watts	60 lumens per watt

Bibliography and Other Research

Information for this measure template has been taken from the PIER research project number 500-01-041-A10 report. This PIER report is available from the California Energy Commission's PIER group as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

The hyperlink for this project is as follows:

http://www.archenergy.com/lrp/advlight_luminaires/project_4_1.htm

Integrated Classroom Lighting

2008 California Building Energy Efficiency Standards

PIER Program - EnergySoft, LLC

January 05, 2006

Overview

Description	Based upon products developed and tested by the PIER research group, it has been demonstrated that adequate classroom lighting levels can be achieved at considerably lower Lighting Power Densities than are currently prescribed in the standards. As part of a PIER research project, with input from representatives of the Collaborative for High Performance Schools (CHPS), a high performance lighting system has been demonstrated that has the potential to save 1/3 of the lighting energy versus current practice. Using a combination of best practices and new technologies, the team developed and tested an integrated classroom lighting system (ICLS) for use in K-12 classrooms. The basic system includes indirect luminaires with energy efficient T-8 lamps and electronic ballast, 96% reflective material within the fixture, a teacher control center located at the front of the classroom, and plug-and-play components.
Type of Change	This measure change is proposed as a revision to the allowed Lighting Power Densities for classrooms in the prescriptive standards. It is proposed that the allowed Lighting Power Densities specified in Table 146-B for schools and Table 146-C for classrooms be reduced to 1.10 watts/square-foot.
Energy Benefits	This measure change will result in reduction in both peak demand, due to the lower installed LPD as well as a reduction in kWh consumption. In retrofit applications, which this code would apply to, the PIER testing demonstrated as much as 35% savings with the use of better lighting technology.
Non-Energy Benefits	Teachers at each of the 6 schools in which the ICLS system was installed were surveyed and provided valuable feedback to the researchers and the manufacturers about the system. Overall, the teachers preferred the ICLS to typical classroom lighting systems. Some teachers expressed the comment that they did not realize the poor quality of light from the typical classroom lighting systems (which were 2X4 lay-in troffers with T-8 lamps and on/off switches located only at the room entryway) until the ICLS was installed.

Environmental Impact	Lighting in classrooms may potentially impact the rate of learning for over 6 million students attending K-12 classes in California. Lighting whiteboards, teaching walls, students' and teachers' desks, and teachers' faces is fundamental to the learning process. New methods of learning and other factors affect the way classrooms should be lighted. These changes mean that old, proven ways to light classrooms are obsolete. Classrooms are becoming computerized environments. Schools are installing cable and fiber networks in over 99% of all new classrooms. Classrooms need glare-free lighting systems with proper light levels for computer use. Indirect lighting, used in the ICLS, is recommended for lighting classrooms by both the Illuminating Engineering Society of North America (IESNA) in their publication RP-3 and by the Collaborative for High Performance Schools (CHPS) in their training materials.
Technology Measures	Measure Availability and Cost The high performance lighting system demonstrated here is made by a number of manufacturers. While these types of fixtures are more expensive, overall, the installed cost of the ICLS (~$2.71 / sq ft) is less than the cost of a typical layout using 15 parabolic troffers (~$2.86 / sq ft.). This is due to a smaller quantity of fixtures needed in the classroom. This study demonstrated that the higher performing technology had a zero first cost impact on the classrooms. Useful Life, Persistence and Maintenance Designing classrooms with this technology does not introduce any significant life, maintenance or persistence issues that do not exist with the use of lower performing fixtures.
Performance Verification	No performance verification issues will arise with a reduction in classroom LPDs.
Cost Effectiveness	This measure was shown to have a zero first cost in the test application studied in the PIER report.
Analysis Tools	As a reduction in the prescriptive LPD, there is no impact on analysis tools.
Relationship to Other Measures	There is no relationship to other measures.

Methodology

The classroom designs developed in these studies had 0.96 watts/square-foot of installed lighting. This is well below the current 1.2 watts/square-foot in the 2005 code. 1.10 watts/square-foot was chosen as a reasonable compromise LPD between the highest performing design and current code. However, it should be pointed out, that with the use of occupancy sensors in the classroom, the LPD for the high efficiency design studied here is reduced to an effective value of less than 0.8. So it is not unreasonable that the 1.0 watt/square-foot value could be considered. Especially since this study has shown that this is the most cost-effective solution. Designers could still easily beat this goal with the use of additional controls. By using daylighting systems, the effective LPDs could be driven down into the 0.65 – 0.70 watt/square-foot range.

While certain classroom designs, such as portables, may not lend themselves to conventional indirect systems, the system demonstrated in the PIER report is suitable for installations even when suspended only 3 inches from the ceiling. In instances where designers were still not inclined to use such a system they could still utilize classroom occupancy sensors in the design, which would allow an effective LPD of 1.375 w/sqft. Either solution would result in a more efficient classroom with lower overall energy use.

Analysis and Results

Working with six California schools, variations of the ICLS were installed in 19 classrooms. Researchers continuously monitored the ICLS and other baseline classrooms for one school year and analyzed the resulting data. The data shows a 30 to 50 percent reduction in energy use in the ICLS classrooms with improved lighting on the teaching walls and better flexibility for adjusting light levels during audio/visual presentations. The ICLS also provides approximately 40 to 70 foot-candles of light on student's desks while maintaining less than 1 watt/square-foot in the classrooms.

Recommendations

In the Standards, Table 146-A should have the category for Schools changed from 1.2 to 1.1
In the Standards, Table 146-B should have the category for Classrooms changed from 1.2 to 1.1.

In the Nonresidential ACM Manual, Table N2-2 should have the category for Schools changed from 1.2 to 1.1.
In the Nonresidential ACM Manual, Table N2-3 should have the category for Classrooms changed from 1.2 to 1.1.

Material for Compliance Manuals

In the Nonresidential Manual, Table 5-2 would have Schools changed from 1.2 to 1.1.
In the Nonresidential Manual, Table 5-3 would have Classrooms changed from 1.2 to 1.1.

This will not affect any other documents or forms.

Bibliography and Other Research

Information for this measure template has been taken from the PIER research project number 500-01-041-A14 report. This PIER report is available from the California Energy Commission's PIER group as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

The hyperlink for this project is as follows:

http://www.archenergy.com/lrp/advlight_luminaires/project_4_5.htm

Bi-level Stairwell Lighting

2008 California Building Energy Efficiency Standards

PIER Program - EnergySoft, LLC

February 3, 2006

Overview

Description	A recent PIER research project has demonstrated the dramatic energy savings benefits of using occupancy sensors with bi-level illumination in stairwell applications in commercial buildings. Since stairwells are typically lit 24 hours a day, the potential for energy savings by reducing lighting to a lower level during unoccupied periods is significant. While this PIER project used a bi-level stairwell fixture, the use of bi-level illumination in general in this application has a much greater impact than currently recognized by the Standards.
Type of Change	This change is proposed to be an addendum to Table 146-A, the Prescriptive Lighting Power Adjustment Factor table. It is proposed to add an additional entry in this table providing credit for use of this technology specifically in stairwell applications. The electronic ballasts employed for this technology must have a Ballast Efficacy Factor (BEF) of 1.48 or greater.
Energy Benefits	To demonstrate the energy savings potential of this technology, four buildings were selected for testing based on how often the stairwells were used by occupants. Baseline measurements were taken prior to the installation of the bi-level stairwell fixtures. In these four buildings, building owners saved between 38 and 49 percent of lighting energy on 24-hour weekdays, and between 47 and 67 percent on weekend days. The percentage of time in dimmed mode ranged from 62 to 82 percent during weekdays, and from 85 to 97 percent on weekends. The energy savings from the application of bi-level technologies to stairwells at the four test sites ranged from 40 to 60 percent. The bi-level illumination technology reduces both peak energy demand and energy consumption. Because these fixtures are on 24 hours per day, both types of energy saving are significant. The BEF of 1.48 or more will ensure that these fixtures will operate efficiently at full load.

Non-Energy Benefits	The PIER study did not have enough data to determine if there will be an extension of lamp life due to the use of this technology. In some application, where the lamp is turned entirely off, the lamp life will probably be shortened. However, due to less operating hours, the actual calendar life of the lamp will be similar. The net result is greater energy savings with similar overall time frequency for lamp replacement. Because of the recent security concerns in the United States, the importance of lighting stairwells for safe emergency egress under extreme conditions has gotten increased attention from both building owners and property insurance companies. Many emergency preparedness experts are questioning whether current minimum light levels called for in life safety codes are really sufficient for emergency egress situations—especially where smoke may be a factor. By utilizing bi-level stairwell illumination, a building owner has the potential to significantly increase light levels in stairwells when needed, yet keep energy costs low. Even though the current Title 24 code will permit the higher footcandles, this will give building owners the ability to achieve these levels without a penalty on energy usage.
Environmental Impact	The issue of safety in the stairwell was considered in the PIER study. In fact, it is very likely that we will see a large increase in lighting levels in stairwells in coming years, due to possible code adoption of a 10 foot-candle requirement in the NFPA. This will dramatically increase the energy savings potential of this technology, and still have the positive benefit of allowing building owners to achieve compliance with this new regulation.
Technology Measures	Measure Availability and Cost At least three lighting fixtures are now in production and offered for sale in California that combine a fluorescent lighting fixture and an occupancy sensor so that it is possible to provide bi-level illumination in stairwells. In addition, the Bi-level control scenario is already encompassed in the Title 24 Standards, and occupancy sensors are an extremely common product. Currently, fixtures that incorporate the bi-level technology are 2-3 times the cost of conventional fixtures. However, this price will drop with the introduction of lower cost multi-step ballast technology. Useful Life, Persistence and Maintenance Persistence of this type of energy savings will be similar to current occupancy sensor based technology.
Performance Verification	It is recommended that the same procedures that are in the standards for performance verification of bi-level illumination in hotel/motel hallways be applied to bi-level illumination products when utilized in stairwells.
Cost Effectiveness	This study demonstrated that the bi-level illumination, even utilizing a fixture that cost three times the price of a conventional fixture, would still show a payback of under 5 years.

Analysis Tools	No impact on analysis tools would result from this proposal. This would simply be a change to the lighting control credits in table 146-A.
Relationship to Other Measures	No other measures would be impacted by this technology, although it might be argued that if the 10 foot-candle rule for stairwells is put into effect, this technology may be the only reasonable way to meet this requirement,

Methodology

The current Standards offer a Lighting Power Adjustment Factor for the use of bi-level illumination in corridors of Hotel/Motel applications. The credit given is a 25% savings adjustment. Clearly, these applications have a considerably higher usage factor than most stairwells in buildings. It is the recommendation that we apply the same savings fraction for stairwell applications in any nonresidential building as we do for the corridor application. Even though the technology has been shown to save 40 - 60%, it is reasonable to discount the savings for controls related problems, and user override of occupancy sensors.

As a follow-up to this, if the 10 foot-candle rule is implemented by NFPA, it is recommended that this technology be considered for adoption as a mandatory measure, perhaps in the 2011 Standards. Typically this section will contain the assumptions used for the analysis of the measure, a description of the base case (current Standards or current practice) and the proposed Standards case.

Analysis and Results

The purpose of the PIER study, upon which this measure template is based, was to test a new type of lighting technology, bi-level stairwell fixtures, in California to determine energy savings, demand reduction, and its acceptance among code-making officials. The bi-level fixtures use a built-in ultrasonic occupant sensor that causes the light to switch to high-level lighting when a stairwell is occupied. After a period of time with no motion detected, the light fixture switches back to low-level, standby lighting.

Previous research, funded by the New York State Energy Research and Development Authority (NYSERDA), was conducted in 2003 by the Lighting Research Center from Rensselaer Polytechnic Institute (RPI.) The fixtures were installed in a high-rise residential complex located on Roosevelt Island just east of Manhattan and a high-rise office building located on Lexington Avenue in New York City. In both cases, the stairwells were not used frequently due to security restrictions. The resulting energy savings were substantial, 53 to 60 percent, when compared to the existing lighting
fixtures. Findings from this NYSERDA study are included in the PEIR report.

Like New York, Californians experience some of the highest energy costs in the country. Introducing technologies that reduce energy consumption can help building owners improve building performance and decrease utility costs. The International Facility Management Association (IFMA) was commissioned to find commercial building owners in California who would be willing to install bi-level fixtures in their stairwells and allow researchers from Lawrence Berkeley National Laboratory (LBNL) to monitor occupancy patterns and lighting energy consumption. The PIER report documents the performance of these fixtures and the building owners' reaction to the fixtures. It also documents the presentations of the bi-level technology along with other LRP technologies and products to various California organizations.

Recommendations

It is recommended that the following language be included in Table 146-A of the Standards:

TYPE OF CONTROL	TYPE OF SPACE	FACTOR
Occupant sensor controlled multi-level switching or dimming system that reduces lighting power at least 50% when no persons are present with a BEF of 1.48 or greater	Hallways of hotels/motels	0.25
	Any stairwells	0.25

Material for Compliance Manuals

Changes to the Nonresidential Manual are included below:

Other Control Credits

Table 146-A of the Standards also provides control credits for the following technologies and spaces:

- Occupant sensor controlled multi-level switches or dimming systems that reduce the lighting power at least 50% in hallways of hotel/motels, any stairwells, commercial and industrial storage stack areas (maximum two aisles per sensor), and library stacks (maximum two aisles per sensor). This can be accomplished by placing half of the lighting in these areas on an occupancy sensor and the remainder on a manual switch. Only the fraction of the lighting that is on the occupancy sensor qualifies for the credit (§146(a)4 "controlled watts of any luminaire…").

In this section of the research report, provide information that will be needed to develop the

Table 0-3 – Standards Table 146-A Lighting Power Adjustment Factors

TYPE OF CONTROL	TYPE OF SPACE		FACTOR
Occupant sensor with "manual ON" or bi-level automatic ON combined with multi-level circuitry and switching	Any space ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, corridor, conference or waiting room		0.20
Occupant sensor controlled multi-level switching or dimming system that reduces lighting power at least 50% when no persons are present with a BEF of 1.48 or greater	Hallways of hotels/motels		0.25
	<u>Any stairwells</u>		<u>0.25</u>
	Commercial and Industrial Storage stack areas (max. 2 aisles per sensor)		0.15
	Library Stacks (maximum 2 aisles per sensor)		0.15
Dimming system			
Manual	Hotels/motels, restaurants, auditoriums, theaters		0.10
Multiscene programmable	Hotels/motels, restaurants, auditoriums, theaters		0.20
Manual dimming with automatic load control of dimmable electronic ballasts with e BEF of 1.48 or greater.	All building types		0.25
Combined controls			
Occupant sensor With "manual ON" or bi-level automatic ON combined with multi-level circuitry and switching in conjunction with daylighting controls	Any space ≤ 250 square feet within a daylit area and enclosed by floor-to-ceiling partitions, any size classroom, corridor, conference or waiting room.		0.10 (may be added to daylighting control credit)
Manual Dimming with Dimmable Electronic Ballasts and Occupant sensor with "manual ON" or automatic ON to less than 50% power and switching	Any space ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, corridor, conference or waiting room		0.25
Automatic Daylighting Controls with Windows (Stepped Switching or Stepped Dimming/Continuous Dimmed) (Numbers on the left side of a slash apply to Stepped Switching or Stepped Dimming. Numbers on the right side of a slash apply to Continuous Dimming)			
	WINDOWS – Window Wall Ratio		
Glazing Type	< 20%	20% to 40%	> 40%
VLT ≥ 60%q	0.20/0.30	0.30/0.40	0.40/0.40
VLT ≥ 35 and < 60%	0/0	0.20/0.30	0.30/0.40
VLT < 35%	0/0	0/0	0.20/0.40
Automatic Multi-Level Daylighting Controls with Skylights			
Glazing Type - Skylights	Factor		
Glazing material or diffuser with ASTM D1003 haze measurement greater than 90%	$10 \times \text{Effective Aperture} - \frac{\text{Lighting Power Density}}{10} + 0.2$ WHERE Effective Aperture is as calculated in the Equation 146-A. Lighting Power Density is the lighting power density of general lighting		

Bibliography and Other Research

Information for this measure template has been taken from the PIER research project number 500-01-041-A16 report. This PIER report is available from the California Energy Commission's PIER group as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

The hyperlink for this project is as follows:
http://www.archenergy.com/lrp/lightingperf_standards/project_5_1.htm

HID Electronic Ballasts

2008 California Building Energy Efficiency Standards

PIER Program - EnergySoft, LLC

January 05, 2006

Overview

Complete the following table, providing a brief sentence or two for each category of information.

Description	Describe the proposed measure or change and how it would apply to buildings regulated by the California Building Energy Efficiency Standards. Describe the building types or systems where the change/measure would most likely apply. Provide appropriate details. Keep the description brief – just a single paragraph, if possible.

Type of Change	Describe how the measure or change would be addressed in the California Building Energy Efficiency Standards, e.g., is the proposed change likely to be a mandatory measure, prescriptive requirement, or compliance option? Would it change the way that trade-off calculations are made? The following describes the types of changes in more detail:

Mandatory Measure	The change would add or modify a mandatory measure. (Mandatory measures must be satisfied whether the prescriptive or performance method is used to show compliance.)
Prescriptive Requirement	The change would add or modify a prescriptive requirement. Prescriptive requirements must be met when using prescriptive compliance. When using performance compliance (computer modeling), prescriptive requirements define a standard design (which sets the energy budget) and are not mandatory.
Compliance Option	The change would add or modify a new measure to the list of existing compliance options for meeting the Standards using the performance approach.
Modeling	The change would modify the calculation procedures or assumptions used in making performance calculations. This change would not add a compliance option or a new requirement, but would affect the way that trade-offs are made.
Other	If the proposed change is not a mandatory or prescriptive requirement, compliance option or modeling assumption or change, please describe what type of change it is.

Does the proposed change modify or expand the scope of the Standards? As a result of the change, would the Standards address new issues or provide requirements for systems or equipment, not previously regulated?

Identify the Standards documents (Standards, ACM, Manuals, compliance forms, etc.) that would need to be modified in order to implement the proposed change. Briefly describe the nature of the change to each document.

Energy Benefits	Describe the benefits of the change/measure, especially energy savings and electricity peak demand reduction. Describe how Time Dependent Valuation (TDV) would affect benefits attributed to the measure. Reference the “Analysis and Results” section below for detailed calculations.
Non-Energy Benefits	Identify non-energy benefits, such as comfort, reduced maintenance costs, environmental benefits, improved indoor air quality, health and safety benefits, productivity, and/or increased property valuation.

Environmental Impact	Does the change/measure have any potential adverse environmental impacts? Is water consumption increased? Does it have an impact on indoor air quality or otherwise affect indoor environmental quality? Does it affect atmospheric emissions (including ozone depleting gases)? Are there environmental or energy impacts associated with material extraction, manufacture, packaging, shipping to the job site, installation at the job site, or other activities associated with implementing the measure in buildings?
Technology Measures	If the measure requires or encourages a particular technology, address the following, otherwise skip this section.

Measure Availability and Cost — Identify the principal manufacturers/suppliers who make the measure (product, technology, design strategy or installation technique), and their methods of distribution. Is the measure readily available from multiple providers? Comment on the current ability of the market to supply the measure in response to the possible Standards change and the potential for the market to ramp up to meet demand associated with the possible Standards change. Identify competing products.

Useful Life, Persistence and Maintenance — Describe the life, frequency of replacement, and maintenance procedures related to the measure. How long will energy savings related to the measure persist? Is persistence related to performance verification, proper maintenance and/or commissioning? If there are issues related to persistence, how can they be addressed? (See Performance Verification below.)

Performance Verification	In this section, identify the type of performance verification or commissioning that is needed in order to assure optimum performance of the measure. For residential buildings, field verification and diagnostic testing are required for many measures. For nonresidential buildings, the parallel is acceptance testing. Here are some questions to ask: Does the technology or design strategy need performance verification or commissioning to insure that it is properly installed and/or performing as designed? How are energy performance, useful life and persistence of savings affected by performance verification or commissioning? What specific performance verification measures or requirements are needed to assure that the measure is properly installed and performing as designed?

Cost Effectiveness	Is the proposed change likely to be cost effective? If the change is a mandatory measure or prescriptive requirement, then it is necessary to demonstrate cost effectiveness. See the "Methodology" and "Analysis and Results" sections below, and present the detailed analysis there. While cost effectiveness justification is not needed for compliance options, it will help make the case for their consideration.
Analysis Tools	What tools would be needed to quantify energy savings and peak electricity demand reductions? Can these benefits be quantified using the current reference method? What enhancements to the reference method are needed, if any? If a measure is proposed as mandatory, then analysis tools are not relevant, since that measure would not be subject to whole building performance trade-offs.
Relationship to Other Measures	Identify any other measures that are impacted by this change. Explain the nature of the relationship.

Methodology

Describe the methodology and approach used to develop the recommendations for the measure. Typically this section will contain the assumptions used for the analysis of the measure, a description of the base case (current Standards or current practice) and the proposed Standards case.

The content of this and the following section will depend on the type of measure proposed.

- For any measure proposed as mandatory or prescriptive, perform life-cycle cost analysis s to demonstrate that the measure is cost effective. The procedures for calculating life-cycle cost effectiveness are documented in *Life-Cycle Cost Methodology, 2008 California Building Energy Efficiency Standards* (available soon). Discuss the measure's cost effectiveness.
- For measures proposed as compliance options, life-cycle cost analysis is generally not necessary, since the measure is not proposed to be part of the baseline level of Standards stringency. However, cost justification may improve the chances of the measure being approved. In this case, this section may explain how the measure is to be modeled with the reference method.
- If the measure is a modeling change, this section may deal with the process of how the modeling assumption and/or algorithm affects trade-offs and accuracy of trade-offs.

Analysis and Results

Describe the results of the research. What was learned? How is it relevant to the Standards? Results are not all computational. Some results are based on market share of equipment and applicability of measure limited to certain applications. Provide the following information as applicable:

- *Energy and Cost Savings.* Document the energy and cost savings results that are summarized in the overview section of the report.
- *Cost-effectiveness.* Document the cost effectiveness of the measure following the Energy Commission methodology referenced earlier.
- *Modeling Rules or Algorithms.* Explain the recommended modeling rule or algorithm, how it was developed and how it improves the Standards.

Recommendations

Summarize the specific recommendations for changing the Standards and/or the ACM Manuals. This section should have specific recommended language and contain enough detail to develop the draft standard in the next phase of work. Use the language from the relevant 2005 document(s), and use underlining to indicate new language and strikethroughs to show deleted language.

Material for Compliance Manuals

In this section of the research report, provide information that will be needed to develop the Residential and/or Nonresidential Compliance Manuals, including:

- Possible new compliance forms or changes to existing compliance forms.
- Examples of how the proposed Standards change applies to both common and outlying situations. Use the question and answer format used in the 2005 Residential and Nonresidential Compliance Manuals.
- Any explanatory text that should be included in the Manual.
- Any data tables needed to implement the measure.

The goal is for the author of the evaluation report to provide materials that can later be incorporated into the Nonresidential or Residential Compliance Manual. Requiring that the author/researcher think about compliance and enforcement issues will result in an improved recommendation, one that is less ambiguous and more workable.

Bibliography and Other Research

Information for this measure template has been taken from the PIER research project number 500-01-041-A18 report. This PIER report is available from the California Energy Commission's PIER group as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

The hyperlink for this project is as follows:

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Building Performance Monitoring

2008 California Building Energy Efficiency Standards

PIER Program - EnergySoft, LLC

February 7, 2006

Overview

Description

In collaboration with building owners, property managers and system vendors, LBNL has developed a specification for energy-oriented performance monitoring capabilities for commercial buildings that can be implemented either as part of an Energy Management Control System or as a standalone system. This specification is intended to be adopted by both private and public building owners and managers and can be bid competitively by vendors.

This performance monitoring specification is designed to provide building owners and operators with necessary information needed to maintain optimum energy performance of the building systems.

The Performance Monitoring Specification contains several levels of specification for monitoring. The Class 1 specification would be something we might expect to see on a simple building with rooftop air conditioning units, while the Class 2 specification would be more likely in buildings with chilled water systems.

Note that this performance monitoring specification not only specifies measurement protocols, but it also specifies both data visualization and data archiving so that the EMCS vendors will provide these capabilities.

Type of Change

It is proposed that the Performance Monitoring Specification be incorporated into the Standards as both a Compliance Option in the Nonresidential Performance Method, and also as a feature related to the Acceptance Requirements.

Two documents will require changes to incorporate this feature. Section 3 of the Nonresidential ACM Manual will require an additional section describing this feature, and Chapter 8 of the Nonresidential Manual where the Acceptance Requirements are described.

In addition, software vendors will need to modify their ACM products to incorporate this feature, and to incorporate the appropriate messages on the PERF-1 form identifying both the feature, as well as the requirement for field verification via the Certificate of Acceptance.

Energy Benefits	By providing monitoring data on the building systems performance, information needed to ensure long term energy savings will be provided to building operators. While the Title 24 standards mandate that energy efficiency be installed in a building, there is no mechanism to ensure that energy efficiency is maintained over the life of the building. The performance monitoring specification is a step towards that goal. The current Title 24 will ensure that a building is energy efficient once operation commences, thanks to the new Certificate of Acceptance procedures. However, once the building is operating, there is no mechanism in place to ensure that the initial energy efficiency will be maintained. The Performance Monitoring Specification includes specific measurement requirements that will function in that capacity. One additional long term benefit associated with this type of technology would be future energy standards where building performance becomes a dynamic compliance issue. The model used in automobiles would be a good example where annual testing of emissions is a requirement. The monitoring technology would provide possible future interfacing with a similar approach for buildings.
Non-Energy Benefits	The Performance Monitoring Specification will provide the building owner the information needed to lower operational and maintenance costs. By providing information related to equipment performance, operators will be able to identify systems that might be in need of maintenance and provide that in a timely fashion. This will, in effect, extend the equipment life. In addition, equipment that might normally be on a maintenance schedule purely based upon time, could easily be configured to a maintenance schedule based upon full load hours of operation. This would alleviate the need for unnecessary equipment maintenance, particularly during seasons of low operation.
Environmental Impact	No perceived negative environmental impacts will result from this technology.

Technology Measures

Measure Availability and Cost

While the monitoring technology (sensors, meters, etc.) have been available for years, the data visualization technology that is very useful in performance monitoring is not usually provided in the basic EMCS software suite. Also the data archiving that is useful in Performance Monitoring is much more extensive than what is typically provided in EMCS.

The basic monitoring points are something that is actually needed in many cases for the completion of the Certificate of Acceptance testing requirements. In the case of this recommendation, the monitoring points would be installed as a permanent part of the building, instead of just being added as part of the final commissioning. Once the cost of functional testing is taken into account, the performance monitoring equipment would have an incremental cost which is very low.

Useful Life, Persistence and Maintenance

The monitoring equipment has a useful life which is equivalent to the equipment that it is monitoring. The only persistence issue that is difficult to determine will be operator intervention based upon the monitored data. While it is entirely possible that no action will be taken based upon the information provided by the system pertaining to efficient operation, it is unlikely that a building owner would implement this technology without any plans to utilize the information.

Performance Verification

Currently, verification procedures are in place to commission the operation of the building systems via the Certificate of Acceptance procedures. The performance monitoring specifications are basically the same concept, only on a permanent basis. It is anticipated that the COA procedures could be slightly modified to ensure not only the initial commissioning of the systems, but also the verification of the monitoring equipment.

Cost Effectiveness

Based upon the assumption that the COA procedures already require a certain amount of temporary monitoring, the incremental cost of the permanently installed performance monitoring equipment will be relatively low. What is difficult to quantify is the cost savings associated with this equipment. However, it is safe to say that if the temporary installation of monitoring equipment has already been shown to be cost effective, and hence included in the Standards, having equipment that monitors on a regular basis should have equal or better cost effectiveness.

Numerous studies have demonstrated the gradual degradation of building performance after the initial commissioning, and recommend re-commissioning of the building after as little as three years. With permanently installed equipment providing this same type of information, as a minimum, the re-commissioning cost could be reduced considerable, if not avoided altogether.

Analysis Tools	In the performance analysis approach in Title 24, the building is assumed to operate with no faults. The simulation tools assume ideal operation of the systems in the building, including daylighting controls, occupancy sensors and mechanical system performance. To properly account for the benefits of the performance monitoring, we need to assume a building that does not operate perfectly. It is proposed to apply a similar methodology as proposed in the Fault Detection and Diagnostic measure templates and assume a less than perfectly performing mechanical system.
Relationship to Other Measures	No other measures are impacted by this feature in the modeling.

Methodology

The methodology applied here is similar in nature to the FDD measure templates that have been prepared; however, since the measure described here does not relate to fault diagnosis, the proposed modeling is slightly different. As outlined in the FDD measure templates, field data has shown that a high percentage of Rooftoop units, AHUs and VAV boxes have one or more faults, the baseline building assumption will include HVAC systems that have imperfect operation. When the Standard building includes economizers, the economizer will be assumed to have a performance degradation of 10%. Thus, the maximum outside air capability of the economizer will be 90%. For DX cooling systems, the Standard building under the performance method will have a 6% degradation factor applied to the cooling EIR. In addition, if the Standard building includes VAV boxes, a 10% degradation factor will be assumed. The minimum airflow ratio of the VAV box, which is typically 30%, will be increased to 33%. Thus, these components are assumed to be "broken" in the same fashion as we do with DX systems that do not include TXVs in the current Standards.

If the proposed building includes the performance monitoring, the economizer performance, if present, would be improved to 95% functional. For DX cooling systems, the EIR degradation would be reduced from 6% to 3%, and any VAV boxes would only have a 5% degradation factor.

Recommendations

The following is recommended language for the Nonresidential ACM Manual. Note that this language includes both the FDD language developed in the previous measure templates with the performance monitoring language being proposed in this measure template.

Equation N2-20 should be modified to include the term F_{fdd}

F_{fdd} Cooling system performance adjustment factor, default = 0.90.
For packaged systems with FDD controls, F_{fdd} shall be 0.96.
For systems with performance monitoring equipment, F_{fdd} shall be 0.93.

Equation N2-2

$$
\begin{aligned}
EERnf_{EWB,ODB} &= 1.0452 \times EER_{EWB,ODB} \\
&+ 0.0115 \times EER_{EWB,ODB}{}^{2} \\
&+ 0.000251 \times EER_{EWB,ODB}{}^{3} \times F_{TXV} \times F_{AIR} \times F_{FDD}
\end{aligned}
$$

In section 2.5.2.6, the entire equation for calculating the COOLING-EIR has been omitted, so it would be suggested that the following language be added, which is based upon the previous ACM Manual:

Description: ACMs shall require the user to input the EER for all packaged cooling equipment that are not covered by DOE appliance standards.

ACMs shall also require the user to input the net cooling capacity, CAPa, at ARI conditions for all cooling equipment.

ACMs shall calculate the electrical input ratio, EIR, according to Equation N2-19

DOE Keyword: COOLING-EIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors at ARI conditions for all equipment documented in the plans and specifications for the building.

Default: Minimum EER as specified in the Appliance Efficiency Regulations.

Modeling Rules for Standard Design (New): For the reference method, the standard design shall assign the EER and EIR of each unit according to the applicable requirements of the Appliance Efficiency Standards or the Standards. The EIR of the equipment will be based on the proposed system with an EER that meets the applicable requirements of the Standards but has the same cooling capacity and ARI fan power as the unit selected for the proposed design.

Modeling Rules for The Standard Design (Existing Unchanged & Altered Existing): ACMs shall use the EER, EIR, and the ARI fan power of the existing system. EIR of the existing equipment must be based on the EER and the ARI fan power of the existing system. ACMs shall model the existing system as it occurs in the existing building. If the permit involves alterations, ACMs shall model the system before alterations.

2.5.3.12 Zone Terminal Controls

Description: ACMs shall be capable of modeling zone terminal controls with the following features:

- *Variable air volume (VAV).* Zone loads are met by varying amount of supply air to the zone.
- *Minimum box position.* The minimum supply air quantity of a VAV zone terminal control shall be set as a fixed amount per conditioned square foot or as a percent of peak supply air.
- *(Re)heating Coil*. ACMs shall be capable of modeling heating coils (hot water or electric) in zone terminal units. ACMs may allow users to choose whether or not to model heating coils.
- *Hydronic heating*. The ACM shall be able to model hydronic (hot water) zone heating.
- *Electric Heating*. The ACM shall be able to model electric resistance zone heating.

ACMs shall require the user to specify the above criteria for any zone terminal controls of the proposed system.

The keyword MIN-CFM-RATIO shall be the minimum box position times 1.1 (not to exceed 1.0) to reflect imperfect operation of the VAV box, unless FDD controls or performance monitoring equipment is installed.

DOE-2 Keyword(s)	MIN-CFM-RATIO ZONE-HEAT-SOURCE
Input Type	Required
Tradeoffs	Yes
Modeling Rules for Proposed Design:	The reference method models any zone terminal controls for the proposed design as input by the user according to the plans and specifications for the building. All ACMs that explicitly model variable air volume systems shall not allow any minimum box position to be smaller than the air flow per square foot needed to meet the minimum occupancy ventilation rate.
Modeling Rules for Standard Design (New & Altered Existing):	For systems 3 and 4, the ACM shall model zone terminal controls for the standard design with the following features: Variable volume cooling and fixed volume heating Minimum box position set equal to the larger of: d) 30% of the peak supply volume for the zone; or e) The air flow needed to meet the minimum zone ventilation rate; or f) 0.4 cfm per square foot of conditioned floor area of the zone. Hydronic heating.

2.5.3.7 Air Economizers

Description: The reference method is capable of simulating an economizer that: (1) modulates
outside air and return rates to supply up to 100% of design supply air quantity as outside air; and, (2) modulates to a fixed position at which the minimum ventilation air is supplied when the economizer is not in operation. The

reference method will simulate at least two types of economizers and all ACMs shall receive input for these two types of economizers:

1. Integrated. The economizer is capable of providing partial cooling, even when additional mechanical cooling is required to meet the remainder of the cooling load. The economizer is shut off when outside air temperature or enthalpy is greater than a fixed setpoint.

2. Nonintegrated/fixed set point. This strategy allows only the economizer to operate below a fixed outside air temperature set point. Above that set point, only the compressor can provide cooling.

The default for MAX-OA-FRACTION shall be 0.9 to represent imperfect operation of the economizer.

DOE Keyword: ECONO-LIMIT
ECONO-LOCKOUT
ECONO-LOW-LIMIT
MAX-OA-FRACTION

Chapter 3 should be modified with the following language:

3.3.20 Systems with Performance Monitoring Equipment

Description: A nonresidential ACM may be approved with the optional capability of controls that monitor system and building performance as follows:

Class 1- Basic: Applied to a single building with a DX cooling systems.

Class 2- Intermediate: Applied to conventional buildings with built up systems which include air handlers, boilers and a chilled water plant.

Table 1 – Performance Monitoring Requirements

Requirement	Class 1 - Basic	Class 2 - Intermediate
Measurements	OA Temp; OA WB-Temp; Duct static pressure; Main power; RTU power; Zone temperatures	Add: MA Temp RA Temp Air handler # SF & RF power; Air handler # flow (cfm); Air handler # Return Damper %; Air Handler # OA Damper %; Air handler # SF VFD freq (Hz)
Visualization	Graphics for metrics results table and floor plan with zones temperatures	Expand metrics results table to include additional metrics. Add graphics for system tables, time series plots of system block trends and system performance.
Data Archiving Recommended	Access Database	Sequel Server/My SQL

DOE Keyword: COOLING-EIR
MAX-OA-FRACTION
MIN-CFM-RATIO

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall model the optional feature of proposed design performance monitoring equipment as input by the user according to plans and specifications for the building. For systems with performance monitoring equipment the cooling system performance adjustment factor F_{fdd} in equation N2-20 shall be 0.93. The economizer MAX-OA-FRACTION keyword shall be 0.95, and for systems that use VAV boxes, the MIN-CFM-RATIO keyword shall be 1.05 times the minimum flow ratio for the terminal box as shown in the plans and specifications.

Modeling Rules for Standard Design (New): ACMs shall determine the standard design according to Table N2-10.

Modeling Rules for Standard Design (Existing Unchanged & Altered Existing): ACMs shall model the existing system as it occurs in the existing building. If the permit involves alterations, ACMs shall model the system before alterations.

Material for Compliance Manuals

It is recommended that Chapter 8 of the Nonresidential Compliance Manual be changed to accommodate this measure since it will require verification as an Acceptance Requirement on the Certificate of Acceptance. The Certificate of Acceptance forms MECH-4-A and MECH-7-A should include the additional information for verification of the performance monitoring equipment.

Bibliography and Other Research

Information for this measure template has been taken from the PIER research contract 500-03-022, Project 4: Performance Monitoring in Large Commercial Buildings, *Performance Monitoring System Specification*, *Developmental Release 1.0, August, 2005*. This PIER report is available from the California Energy Commission's PIER group as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

The Performance Monitoring Specification is also posted at:

http://cbs.lbl.gov/performance-monitoring/specifications .

Displacement Ventilation

2008 California Building Energy Efficiency Standards

PIER Program - EnergySoft, LLC

February 2, 2006

Overview

Description	Displacement Ventilation (DV), a space conditioning technology in use in Europe since the 1970's has the ability to reduce energy usage in buildings due to a number of energy saving strategies not found in conventional overhead mixing systems. Research and development of modeling procedures done by the CALIFORNIA ENERGY COMMISSION PIER group are presented to facilitate the inclusion of DV into the Standards for energy analysis purposes.
Type of Change	This measure proposal is a Compliance Options proposal for modeling of Nonresidential buildings in the standards. Just as the Nonresidential ACM manual now includes optional modeling for underfloor air distribution systems, it is proposed to incorporate the DV systems in to modeling procedures.

Energy Benefits

The fundamental principle involved in a DV system is to supply significantly warmer supply air temperatures during cooling mode, typically 63°F to 68°F. With the use of higher supply air temperatures comes the ability to operate in economizer mode many more hours each year. When producing the higher supply air temperatures, chilled water systems have the ability to operate at much higher chilled water temperatures, thus resulting in a significant increase in the chiller efficiency when producing chilled water. In addition, for systems that will be requiring reheat, additional heating and cooling energy is saved since they will be reheating air that is cooled to only 65°F versus a conventional system that has cooled the air to 55°F.

By not mixing the air in the room, the DV system results in more of a stratification effect. Thus, much of the heat in the space will rise towards the ceiling, where it will be exhausted by the high return air register. Thus, a portion of the cooling load in the space, including occupant heat gain, lighting and equipment, never appears as a cooling load. Overall, DV systems have the potential to save from 30-50% of the cooling energy based upon demonstrated savings in the case study buildings in the reports.

With a carefully designed DV system, the potential increase in fan energy usage associated with moving larger volumes of air can be mitigated. By taking advantage of the reduction in space loads from the use of the DV system, there is a downsizing potential for the cooling system. Much of the potential energy increase from the fan system will be recouped when this reduction is factored into the system design and fan selection.

Non-Energy Benefits

Because DV does not mix air like a conventional overhead system, there is a significant improvement in indoor air quality. By not mixing pollutants, and circulating them around the room, school classrooms in particular can benefit from this type of system. In addition, because this system is very low velocity, there are acoustic benefits associated with this type of system. A third benefit is the ability to downsize the mechanical system. Since a large portion of heat gain in the space is simply exhausted out the return air, this heat gain never actually shows up as a load on the mechanical system. This results in a smaller, more efficient system.

Environmental Impact

The only environmental impacts associated with the use of this system are positive benefits such as IAQ.

Technology Measures

Displacement Ventilation does not require the use of any particular manufacturer's equipment, nor any special technology that has not been available for years. It is simply the application of currently available cooling systems, designed in a fashion that utilizes the benefits of a stratified, non-mixing cooling system.

It is anticipated that the measure life will be improved with this type of system, since it will have higher hours of operation in economizer mode, and a lot less hours of operation of the cooling system.

Performance Verification	Since this is a nonresidential measure recommendation, it is expected that the new Certificate of Acceptance (COA) forms will encompass the performance verification of the system in the field. Currently, the MECH-2-A, MECH-3-A and MECH-4-A encompass testing procedures that will cover the mechanical system verification necessary for this type of system.
Cost Effectiveness	Not a lot of data is available on the cost effectiveness of this type of system, since the use of DV in the United States is fairly new. However, several California pilot projects have demonstrated significant energy savings, with only a minor increase in overall system design cost. San Diego Unified School District is embarking on an evaluation project for DV technology in which five campuses will be used for sample installations of the technology.
Analysis Tools	The current reference method, DOE-2.1E, as well as derivatives such as DOE-2.2 are not well suited to modeling these types of systems. Simplifications can be made in the modeling to approximate the energy benefits, however, these approximations will underestimate the true energy savings of this system. Newer programs such as EnergyPlus have been enhanced through work by the PIER group to more accurately represent the performance of the DV systems. However, since EnergyPlus is not scheduled to be implemented as the reference method in the 2008 Standards, this measure template has been written in a more general format to encompass the current modeling tools, as well as future products like EnergyPlus.
Relationship to Other Measures	No other measures are impacted by this compliance option.

Methodology

This measure change proposal does not propose to make any changes to the standard system comparison flowchart for this system. Instead, it proposes to include an additional optional system type in Section 3.3.5 of the Nonresidential ACM manual. Based upon modeling procedures developed by the PIER team and outlined in the report, this measure change proposes that additional language be included in the ACM manual to allow the modeling of these systems. However, it should be noted that different software tool vendors may approach this modeling issue from a different perspective, as outlined in the materials. Therefore, rather than describing the more detailed EnergyPlus modeling that has been developed, which would preclude the use of the simplified models, this template provides latitude for modeling with the tools currently in the marketplace.

Analysis and Results

Several examples of DV system have been completed recently. The Blue Valley North High School in Overland Park Kansas is one example of an application to classroom cooling. In this case, DV was applied as a retrofit. Despite the need to increase the ventilation relative to the older system to meet newer codes, the new DV system still showed a 20% electricity savings on the project.

Another example of a DV system installed north of Sand Diego, in Cardiff, is the Cardiff Public Library project. Designed to take advantage of the cool, Oceanside location, this system relies on a 17.7 ton VAV system, and delivers air between 62°F to 67°F.

Recommendations

This is proposed as a compliance option, so only changes to the Nonresidential ACM manual are proposed.

Material for Compliance Manuals

In Chapter 2, it is suggested that the supply air temperatures for conventional systems be fixed at 55 degrees. In tables N2-11 through N2-14, the following would be changed:

Min Supply Temp: ~~50 ≤ T ≤ 60 DEFAULT:~~ 55

In Chapter 3 of the Nonresidential ACM Manual under optional systems the following language is suggested based upon the referenced studies:

3.3.16 Displacement Ventilation Systems.

Description: An HVAC system, usually using chilled water coils, provides air (typically 63°F to 68°F) to a space at very low velocities, delivered close to the floor. Air is exhausted from the space near the ceiling, and due to the low velocity of air delivered, there is a stratification of air in the space. Although this system uses warmer supply air temperatures it only has about 20% higher air delivery volume compared to a conventional overhead system as it provides displacement of some of the thermal loads.

The ACM shall automatically assign the portion of heat gain from occupants, lighting and equipment to the plenum zone, or some other zone defined to represent the stratification effect of the DV system. Default assignment fractions for the portion of heat to the space versus the portion to the plenum shall be as follows:

Load Component	Percent to Space	Percent to Plenum
People	67%	33%
Lights	50%	50%
Equipment	50%	50%

The ACM shall allow the use of a higher supply air temperature, as well as the application of supply temperature reset by either demand or outdoor dry-bulb temperature. Additionally, the ACM may also optionally accommodate higher chilled water temperatures on systems that utilized chilled water coils.

The ACM shall make an entry in the special features and remarks section of the PERF-1 report noting the use of a displacement ventilation system.

DOE Keyword:	LIGHTING-W/SQFT EQUIPMENT-W/SQFT AREA/PERSON MIN-SUPPLY-T CHILL-WTR-T
Input Type:	Default
Tradeoffs:	Yes
Modeling Rules for Proposed Design:	The ACM shall model all optional displacement ventilation system features as input by the user according to the construction documents for the building.
Modeling Rules for Standard Design (New):	The ACM shall model the standard design according to the requirements of the Required Systems and Plant Capabilities.
Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):	ACMs shall model the existing system as it occurs in the existing building. If the permit involves alterations, ACMs shall model the system before alterations.

Bibliography and Other Research

Information for this measure template has been taken from the PIER research project number 500-03-097-A9 report and the Energy Design Resource work. This PIER report is available from the California Energy Commission's PIER group as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

One PIER report which is almost 8 MB is available at:

http://www.energy.ca.gov/reports/2003-11-20_500-03-097F-A09.PDF

An additional PIER report which documents the modeling is available at:

http://www.energy.ca.gov/reports/2003-11-20_500-03-097F-A07.PDF

In addition, work done for the Energy Design Resources (EDR) group was also the basis of the change proposal. The EDR report which includes case studies is available at the following links:

http://www.energydesignresources.com/docs/db-05-displacementventilation.pdf

An additional report produced by the EDR group which describes similar modeling techniques is available at:

http://www.energydesignresources.com/docs/hg-underfloor.pdf

Natural Ventilation for Cooling

2008 California Building Energy Efficiency Standards

PIER Program - EnergySoft, LLC

February 7, 2006

Overview

Description	In recent years, much interest has been focused on environmentally friendly buildings. As green building standards such as LEED (Leadership in Energy and Environmental Design) and GGHC (Green Guidelines for Health Care) have become more popular, there has been a push to utilize naturally ventilated buildings instead of using traditional forced air cooling systems. Clearly, the energy savings potential for this type of approach to cooling a building is substantial; however, one obstacle to this approach has been a lack of recognition by the Title 24 energy standards for this design strategy. Recently, the PIER group has completed a number of research projects related to low energy cooling of buildings, and one in particular focuses on algorithmic enhancements to the EnergyPlus energy modeling software to allow modeling of natural ventilation. This measure template proposes modifications to the Nonresidential ACM manual that will provide some level of recognition in the modeling tools for a naturally ventilated building.
Type of Change	This change template is proposed as a modeling change to the modeling of the Title 24 Standard Building, rather than a change to the way we model the proposed building. This template does not propose that natural ventilation be considered a special compliance option, since we do not have enough sophistication in the current tools to model the thermal interactions that are associated with the natural ventilation modeling described in the PIER study. Instead, the Standard building modeling will be change slightly, so that it recognizes the fan energy savings implications of this technology. Savings for cooling energy are not proposed. Once EnergyPlus becomes the reference method, it would be suggested that a compliance option be developed that does recognize the sophistication contained in the modeling as referenced in the PIER report.

Energy Benefits

In the past 20 or 30 years, there has been a significant move towards air conditioning buildings in coastal climates. What used to be considered a luxury, is now the norm in these areas. Yet, the potential for using natural ventilation as a strategy still remains. As green building compliance becomes a criteria for many building owners, designers are seeking ways to reduce energy usage, particularly cooling energy. Many recent examples of naturally ventilated buildings in coastal areas of California have demonstrated massive energy savings; one strategy contributing to the savings is natural ventilation. Since cooling and fan power can consume more than 30% of the building energy usage, and the majority of this energy is consumed during peak conditions, the savings potentials are huge.

Non-Energy Benefits

When designed properly, naturally ventilated buildings can provide a much more pleasant working environment for the occupants. Giving occupants individual control over their operable windows, and hence their climate has been shown to be much more desirable than simply pumping a building full of conditioned air. Naturally ventilated buildings will have improved indoor air quality, since the building will be totally reliant upon outside air, except in situations where outside air quality may be poor. These applications would not be good candidates for this technology.

By eliminating the cooling system, we eliminate the maintenance associated with it, and the harmful refrigerants used within the cooling system.

Environmental Impact

By encouraging the use of natural ventilation for cooling in buildings the state will realize on positive environmental benefits.

Technology Measures

Measure Availability and Cost

There is no special technology being promoted, other than the proper design of a building to permit natural ventilation to function as a cooling source. Obviously, the cost is much lower than a conventional cooling system, since the main factors involved will be operable windows and floor plan design.

Useful Life, Persistence and Maintenance

Persistence is probably the one sticking point to this proposal. Will the building owner and occupants be satisfied with the use of natural ventilation, or will they eventually retrofit the building and add cooling? For this reason, this measure template does not propose a wholesale credit of cooling energy and fan power for buildings that utilize natural ventilation. Rather, it proposes a very modest credit associated with the fan power, with the assumption that perhaps someday, a cooling system might be added to the building.

It is suggested that restrictions be placed on the design of the building and any potential mechanical systems that might provide cooling when this credit is applied. This is discussed further under the Methodology section.

Performance Verification	It is recommended that this measure appear as a feature on the PERF-1, under the special features and modeling assumptions section. The building department would be alerted to the credit taken for a naturally ventilated space, and the restriction would indicate that no cooling systems be present, and no fan systems for ventilation.
Cost Effectiveness	This measure has lower first cost to the building owner, and lower operating costs, so it will always be cost effective.
Analysis Tools	This proposal does not require any changes to the analysis tools that we use, nor to the reference method. Although it would be more desirable to adopt an entirely new reference method such as EnergyPlus that can model natural ventilation, this would be an unrealistic proposal at this point.
Relationship to Other Measures	This change is a slight modification to the way the reference building energy use is calculated but does not impact other measures.

Methodology

Back in 1992, the Nonresidential ACM manual included language which provided credits to buildings that utilized low fan power cooling systems. This language was revised in the 1995 Standards change, and credit was removed. The proposal in this template is to restore that language, but to add additional qualifying criteria to the credit.

One obvious criticism of the suggestion to credit natural ventilation is that certain building types already utilize natural ventilation. As an example, a warehouse application in most instances would not rely on a forced air system to provide cooling. For this reason, this measure change proposes to restrict the credit to only Office and School occupancies. Other, denser occupancy types will probably not be a good candidate for this application given the larger amounts of internal heat gain and ventilation needs. It may even be argued that schools are not a good candidate, but work done by the California High Performance Schools group has focused on low energy cooling applications in K-12 schools. With proper classroom design, this strategy could be accomplished. In particular, college and university campuses would be good candidates for this strategy.

The next issue surrounds what climates would benefit from this strategy. Obviously, inland valley and desert climates would not be a good application of this feature. Even if we allowed the credit, chances are pretty good that after a certain period, the building owner would be forced to retrofit the building with cooling. For this reason, this change proposal recommends only coastal climates be included. These include climate zones 1, 3, 5 – 7 and 16. Note that 16 was included even though it is not coastal, since it is a cold climate similar to 1.

It is recommended that the following additional restrictions be place on the use of natural ventilation and that notes appear on the PERF-1 to this effect, when this credit is applied:

> Plans and specification shall show minimum ventilation requirements have been met per Standards section 121.

No supply air fans or exhaust fans (other than bathroom exhaust fans) shall be used for cooling or ventilation.

The modeling methodology suggested here is not to change the way we model the proposed building. If it has natural ventilation, and no fans for ventilation, we would leave that modeling exactly as it appears in the Nonresidential ACM Manual.

However, on the reference building, when we eliminate the fans that provide ventilation, there is no recognition of this energy savings measure. Current ACM procedures have the reference building fan power track the proposed, all the way to zero. Hence, the elimination of the fans is not recognized. The proposal here is to have the reference building still include a very minor fan power allotment, 0.40 watts per square foot. This value was not chosen arbitrarily, but rather dates back to the 1992 ACM Manual procedures. The net result of this change is that we will see a modest energy credit for these types of systems.

Recommendations

The following changes are recommended in Chapter 2 of the Nonresidential ACM Manual:

2.5.3.5 Fan Power

Description

ACMs shall model all HVAC fans in the systems that are required to operate at design conditions. These include supply fans, exhaust fans (that operate during peak), return fans, relief fans, and fan power terminal units (either series or parallel). The reference program models the fan system power demand using the fan power index (FPI). Fan power index is defined as the power consumption of the fan system divided by the volume of air moved (W/cfm).

For each fan that operates during normal HVAC operation (except for the fan-coil system serving the residential unit of a high-rise residential building or a hotel/motel guest room), ACMs shall require the user to input: 1) the design BHP; 2) the design drive motor efficiency; and, 3) the design motor efficiency, all at peak design air flow rates. Exhaust fans that are manually controlled (such as bathroom fans) may not operate at design conditions and therefore shall **not** be included in the fan system power demand calculations. The reference method calculates the FPI for each fan system according to the following equation:

Equation N2-3

$$FPI = \frac{746}{CFMs}\left[\frac{BHPs}{\eta ds \times \eta ms} + \frac{BHPr}{\eta dr \times \eta mr} + \frac{BHPo}{\eta do \times \eta mo}\right]$$

where:

FPI	=	fan power index, [W/cfm]
CFM_S	=	peak supply air flow rate, [ft³/min]
BHP_S	=	brake horsepower of supply fan at CFM_S [hp]
BHP_r	=	brake horsepower of return fan at CFM_S [hp]
BHP_o	=	brake horsepower of other fans at CFM_S [hp]

η_{ms} = supply motor efficiency [unitless]

η_{mr} = return motor efficiency [unitless]

η_{mo} = other motor efficiency [unitless]

η_{ds} = supply drive efficiency [unitless]

η_{dr} = return drive efficiency [unitless]

η_{mo} = other drive efficiency [unitless]

If the user does not input the design brake horsepower (BHP) and the peak supply air flow rate (cfm) for forced air systems, the ACM shall assume that no mechanical compliance will be performed and shall model the default mechanical system according to the rules in Section **Error! Reference source not found.** (modeling default heating and cooling systems).

ACMs shall allow the modeling of naturally ventilated spaces, in which case, the fan power input by the user shall be allowed to be zero. The following criteria must be met to qualify as a naturally ventilated space:

a) Only buildings in Climate Zones 1, 3, 5-7 and 16 shall qualify.
b) Only Office and School occupancies shall qualify.
c) Plans and specification shall show minimum ventilation requirements have been met per Standards section 121.
d) No supply air fans or exhaust fans (other than bathroom exhaust fans) shall be used for cooling or ventilation.

The ACM shall note any spaces that use natural ventilation in the special features and modeling assumptions section of the PERF-1.

Modeling Rules for Standard Design (New):

The reference method determines the standard design fan power as follows for forced air systems :

a) For systems 1, 2, and 5 with proposed FPI ≤ 0.80: The standard design FPI shall be the same as the proposed design.

b) For systems 1, 2 and 5 and proposed FPI > 0.80: The standard design FPI shall be 0.80.

c) For systems 3 and 4 and proposed FPI ≤ 1.25: The standard design FPI shall be the same as the proposed design.

d) For systems 3 and 4 and proposed FPI > 1.25: The standard design FPI shall be 1.25.

The reference method determines the standard design fan power as follows for spaces that meet the criteria for naturally ventilated spaces:

a) For systems 1-5: The standard design FPI shall be 0.40.

The reference method shall use the appropriate minimum nominal full-load motor efficiency from **Error! Reference source not found.**.

Material for Compliance Manuals

This measure is not recommended as a compliance option, so no changes to the compliance manuals will be required.

Bibliography and Other Research

Information for this measure template has been taken from the PIER research project number 500-03-097-A9 report and the Energy Design Resource work. This PIER report is available from the California Energy Commission's PIER group as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

The PIER report which is almost 8 MB is available at:

http://www.energy.ca.gov/reports/2003-11-20_500-03-097F-A09.PDF

Under Floor Air Distribution

2008 California Building Energy Efficiency Standards

PIER Program - EnergySoft, LLC

February 2, 2006

Overview

Description	In recent years, California has seen surge in popularity of the Underfloor Air Distribution (UFAD) systems as a means for space conditioning. A UFAD system is basically a low energy cooling system that delivers warmer cooling supply air through air diffusers located in a floor plenum space. While the UFAD system is still being studied by the CALIFORNIA ENERGY COMMISSION's PIER group, and advanced modeling procedures are being developed for use in modeling tools such as EnergyPlus, current ACM modeling procedures are non-specific on modeling guidelines. Based upon work completed as part of the PIER work, this measure template presents more specific language for inclusion in the ACM manual to facilitate modeling these systems with the current tools in use in California.
Type of Change	This measure proposal is a Compliance Options proposal for modeling of Nonresidential buildings in the standards. While the Nonresidential ACM manual now includes some brief language pertaining to modeling of UFAD systems, this proposal suggests more precise language.

Energy Benefits

UFAD systems provide cooling supply air streams at significantly warmer temperatures than conventional system, typically 60°F to 68°F. With the use of higher supply air temperatures comes the ability to operate in economizer mode many more hours each year. When producing the higher supply air temperatures, chilled water systems have the ability to operate at much higher chilled water temperatures, thus resulting in a significant increase in the chiller efficiency when producing chilled water. In addition, for systems that will be requiring reheat, additional heating and cooling energy is saved since they will be reheating air that is cooled to only 65°F versus a conventional system that has cooled the air to 55°F.

Since UFAD systems deliver air at lower velocities than conventional system, there is more potential for stratification, since room air is mixed less. Thus, a certain portion of the heat in the space will rise towards the ceiling, where it will be exhausted by the return air register. The overall result is that a portion of the cooling load in the space, including occupant heat gain, lighting and equipment, never appears as a cooling load. Given the fact that at any given point in time, at least some portion of the return air will be exhausted due to outside air requirements, this heat gain will also be exhausted. In fact, because this system runs in economizer mode many more hours of the year dues to the higher supply air temperatures, this effect will be greatly amplified.

Although underfloor systems operate at both higher supply air temperatures and flow rates than conventional overhead systems, with careful design, they can consume less energy than a conventional overhead system. Proper design of the system will result in a reduction in air distribution system pressure drop, reducing the overall fan power needed to supply space conditioning needs.

Non-Energy Benefits

One of the most significant benefits of a UFAD system is the flexibility provided to building owners and occupants in space arrangements. Since the UFAD system utilizes an elevated floor system, the plenum space under the floor provides an ideal space for routing wires and cables. This type of system, commonly referred to as an access floor system, has the ability to remove the floor panels so owners and occupants can quickly and easily rearrange space layouts as the need arises.

Air delivery in a UFAD system is at a much lower velocity, which results in much less mixing of air. Unlike a conventional overhead system that mixes supply air with space air, the UFAD system relies on a stratification effect to displace warmer air towards return air register located in the ceiling. The net result is that pollutants will stratify towards the ceiling and be carried away, resulting in a significant improvement in indoor air quality. Another benefit is the ability to downsize the mechanical system. Since a large portion of heat gain in the space is simply exhausted out the return air, this heat gain never actually shows up as a load on the mechanical system. This results in a smaller, more efficient system

Environmental Impact	The only environmental impacts associated with the use of this system are positive benefits such as improved Indoor Air Quality associated with not mixing the air.
Technology Measures	UFAD Systems do not require the use of any particular manufacturer's equipment, nor any special technology that has not been available for years. It is simply the application of currently available cooling systems, designed in a fashion that utilizes the benefits of a stratified, non-mixing cooling system. It is anticipated that the measure life will be improved with this type of system, since it will have higher hours of operation in economizer mode, and a lot less hours of operation of the cooling system.
Performance Verification	This measure is already included in the 2005 ACM Manual. The new Certificate of Acceptance (COA) forms currently encompass the performance verification of the system in the field. Currently, the MECH-2-A, MECH-3-A and MECH-4-A encompass testing procedures that will cover the mechanical system verification necessary for this type of system. It may also be beneficial to extend the COA requirements related to economizer to encompass more extensive testing of this feature due to the energy savings potential with this type of system, although this same testing would also benefit any system that relies on the economizer for savings.
Cost Effectiveness	In several of the reports referenced at the end of this measure template, it is pointed out that the UFAD system will result in a cost increase in the overall building cost, mainly driven by the cost of the access floor system. On a strict energy basis, it will be difficult to demonstrate cost effectiveness. However, these systems are being installed for many other reasons, including the space flexibility issue, more comfortable indoor environment, and indoor air quality benefits. Taken as a whole, and particularly including tenant remodel costs, these systems do show overall cost effectiveness.
Analysis Tools	The current reference method, DOE-2.1E, as well as derivatives such as DOE-2.2 are not well suited to modeling these types of systems. Simplifications can be made in the modeling to approximate the energy benefits, however, these approximations will underestimate the energy savings of this system. Newer programs such as EnergyPlus are being enhanced through work by the PIER group to more accurately represent the performance of the UFAD systems. However, since EnergyPlus is not scheduled to be implemented as the reference method in the 2008 Standards, this measure template has been written in a more general format to encompass the current modeling tools, as well as future products like EnergyPlus.
Relationship to Other Measures	No other measures are impacted by this compliance option.

Methodology

This measure change proposal does not propose to make any changes to the standard system comparison flowchart for this system. Instead, it proposes to modify the language pertaining to optional system types in Section 3.3.5 of the Nonresidential ACM manual. Based upon modeling procedures developed by the PIER team and outlined in the report, this measure change proposes that more precise language be included in the ACM manual to allow the correct modeling of these systems. However, it should be noted that different software tool vendors may approach this modeling issue from a different perspective, as outlined in the materials. Therefore, rather than describing the more detailed EnergyPlus modeling that has been developed, which would preclude the use of the simplified models, this template provides latitude for modeling with the tools currently in the marketplace.

Analysis and Results

Data at the Center for the Built Environment (CBE) website shows 244 UFAD systems registered as being under construction or built as of March 2005. Many, many more projects have been built using the UFAD system that have not been registered on this site. Ultimately, this system has become quite popular, and is being built despite the fact that we do not have prescribed procedures and tools to quantify precisely the energy savings benefits. As a move towards facilitating more accurate modeling of these systems, the language below has been developed to provide more guidance in the ACM manual for software vendors on how to address these systems.

Recommendations

This is proposed as a compliance option, so only changes to the Nonresidential ACM manual are proposed.

Material for Compliance Manuals

In Chapter 2, it is suggested that the supply air temperatures for conventional systems be fixed at 55 degrees. In tables N2-11 through N2-14, the following would be changed:

Min Supply Temp: ~~50 ≤ T ≤ 60 DEFAULT:~~ 55

In Chapter 3 of the Nonresidential ACM Manual under optional systems the following language is suggested based upon the referenced studies:

3.3.17 Underfloor Air Distribution Systems.

Description: A central system provides air (typically 60°F to 68°F) to an underfloor plenum. It is distributed to the space using either passive or active grilles (cooling), across reheat coils or through fan-powered boxes (typically variable speed with reheat coils). Although this system uses warmer supply air temperatures it usually has a similar airflow to a conventional overhead system as it provides displacement of some of the thermal loads.

The ACM shall automatically assign the portion of heat gain from occupants, lighting and equipment to the plenum zone, or some other zone defined to represent the stratification effect of the DV system. Default assignment fractions for the portion of heat to the space versus the portion to the plenum shall be as follows:

Load Component	Percent to Space	Percent to Plenum
People	75%	25%
Lights	67%	33%
Equipment	67%	33%

The ACM shall allow the use of a higher supply air temperature, as well as the application of supply temperature reset by either demand or outdoor dry-bulb temperature. Additionally, the ACM may also optionally accommodate higher chilled water temperatures on systems that utilized chilled water coils.

The ACM shall make an entry in the special features and remarks section of the PERF-1 report noting the use of an underfloor air distribution system.

DOE Keyword:	LIGHTING-W/SQFT EQUIPMENT-W/SQFT AREA/PERSON MIN-SUPPLY-T CHILL-WTR-T
Input Type:	Default
Tradeoffs:	Yes
Modeling Rules for Proposed Design:	The ACM shall model all optional underfloor air distribution system features as input by the user according to the construction documents for the building.
Modeling Rules for Standard Design (New):	The ACM shall model the standard design according to the requirements of the Required Systems and Plant Capabilities.
Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):	ACMs shall model the existing system as it occurs in the existing building. If the permit involves alterations, ACMs shall model the system before alterations.

Bibliography and Other Research

Information for this measure template has been taken from the PIER research project number 500-03-097-A9 report and the Energy Design Resource work. This PIER report is available from the California Energy Commission's PIER group as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

One PIER report which is almost 8 MB is available at:

http://www.energy.ca.gov/reports/2003-11-20_500-03-097F-A09.PDF

Additional work sponsored by PIER on this topic can be found at:

http://www.cbe.berkeley.edu/underfloorair/

An additional PIER report which documents the modeling is available at:

http://www.energy.ca.gov/reports/2003-11-20_500-03-097F-A07.PDF

In addition, work done for the Energy Design Resources (EDR) group was also the basis of the change proposal. The EDR report which includes case studies is available at the following link:

http://www.energydesignresources.com/docs/db-02-underfloordistro.pdf

An additional report produced by the EDR group which describes similar modeling techniques is available at:

http://www.energydesignresources.com/docs/hg-underfloor.pdf

Appendix B:

PowerPoint Presentation to 2008 Nonresidential Standards Workshop

Appendix C:
ACM Chapter 5 Language Corrections

Development of Recommendations to Integrate Emerging Technologies into the 2008 Nonresidential Standards

Appendix C

ACM Chapter 5 Language Corrections

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CEC Agreement #: 500-05-003

Publication Number: (in process)
June 1, 2006

Appendix C – ACM Chapter 5 Language Corrections

Reference Method Comparison Tests

This chapter explains the methods used to test the modeling and input capabilities of Alternative Calculation Methods (ACMs) relative to the reference program. The ACM shall be able to accept all required inputs but it need not be capable of modeling all features as long as it automatically fails proposed designs with features beyond its accurate modeling capabilities. For example, a simplified calculation method modeling only single zone HVAC systems could be approved if it automatically fails proposed designs that enter multi-zone HVAC systems for the proposed design. For ACMs with limited capabilities, the vendor shall inform users that the ACM is not capable of modeling certain features. While most of the tests are performed in three climate zones, some of the tests use other climate zones.

There are a total of 76 specified tests. All the runs described in this chapter shall be performed with the ACM, and run results shall be summarized on the forms contained in Appendix NA.

Overview

ACMs calculate six components of annual building source energy use:

1. Lights
2. Space cooling
3. Space heating
3. Indoor fans
4. Receptacles
5. Service water heating

To test the minimum ACM capabilities, it is necessary to perform a series of computer runs. Each computer run represents a systematic variation of one or more features that affects TDV energy use. Some of the parametric runs are performed in several climate zones for more than one prototype building. Most, however, are designed for only one prototype in just one or two of the climate zones.

For an ACM to be approved, the criteria described in Section 5.1.4 shall be met. This criteria compares the energy use differences, calculated using the ACM, to the energy use differences calculated using the reference calculation method. The energy use difference or compliance margin for each of these is the difference between any simulated proposed building design TDV energy and the standard design's TDV energy. For this comparison the same proposed design and corresponding standard design shall be used for both the candidate ACM and the reference program. A candidate ACM shall meet all of the tests described in this manual.

The ACM vendor is responsible for running the tests for the candidate ACM and the reference method. The vendor shall provide documentation, reasons and engineering justification for all inputs to the ACM and the reference method.

Base Case Prototype Buildings

The tests are performed with four prototype buildings, summarized in the following paragraphs. The letter designation is used as part of the label for each computer run.

A) This prototype is a one-story building measuring 30 ft by 75 ft and is 12 ft high. Glass exists in a continuous band around the entire building perimeter with the sill 2.5 feet above the floor. The building has a single thermal zone.

B) This prototype is a two-story building measuring 60 ft by 60 ft and is 24 ft high. Glass exists in a mostly continuous band around the entire building perimeter on each floor with the sill at 2.5 ft above the floor. Most tests using prototype B have no interior zones. The building has four thermal zones per floor that are 15 ft deep. In most of the tests using this prototype the interior zones have been purposely removed to increase the sensitivity to envelope measures using separate orientations and wall types for each thermal zone. The prototype should have adiabatic, mass-less walls separating the perimeter zones from the unconditioned interior zones. These separate zones are more sensitive to the measures examined than an envelope-dominated single zone which can mask orientation and individual wall effects. The sensitivity to HVAC sizing methods is also increased when this prototype is envelope dominated.

   In some tests to measure internal energy use differences or economizer cycle sensitivity, the 30 ft by 30 ft interior space becomes two conditioned zones (one on each floor) served by a separate package variable air volume system. In these cases there are five thermal zones per floor.

C) This prototype is a six-story building measuring 60 ft by 60 ft by 66 ft high. Glass exists in a mostly continuous band around the entire perimeter of the building on each floor with the sill 2.5 ft above the floor. The building has a total of fifteen thermal zones: Five on the first floor, five on the middle floors and five on the top floor. A multiplier of four is used for the middle floors.

D) This prototype represents a tenant improvement space in that it has only two exterior walls with two demising "party" walls. The "party" walls are each adjacent to an unconditioned space of the same dimensions as the conditioned space (viz. 20 ft wide, 60 ft deep and 12 ft high). These party walls have nominal 2x4 steel stud framing with R-13 insulation between framing members and 0.5" sheetrock on either side [CONS = IV11-A3]. The unconditioned space has three other exterior walls that use the IV11-A2 wall-type construction. The roof/ceiling of the unconditioned spaces has R-11 insulation between 2x6 wood framing members [[IV3-A2]]. The D prototype building (both conditioned and unconditioned spaces) has a slab-on-grade floor. The unconditioned spaces are modeled using a slab without carpet or pad and with no slab edge insulation. For the conditioned space, the back wall is heavyweight concrete with no windows and a wood door and the front wall is a steel-framed wall with glazing. The space is 20 ft wide and 60 ft deep and has a height of 12 ft. The glazing begins at ground level but varies in height from 4.8 to 6 ft. Tests with this prototype use overhangs and skylights and rotate the whole building geometry.

The base case prototype buildings have the same geometry and zoning in all climate zones. Default building parameters for the proposed designs are indicated for each series. Parameters not described or defaulted in the series are those given in Appendix NF.

No test shall model NIGHT-CYCLE-CONTOL as CYCLE-ON-ANY, but default to STAY-OFF. This is a neutral credit with no trade off and both the standard and proposed design will use the same.

For all concrete slabs on grade, slab edge conditions shall be modeled as per Section 2.3.6.1 of NonRes ACM manual.

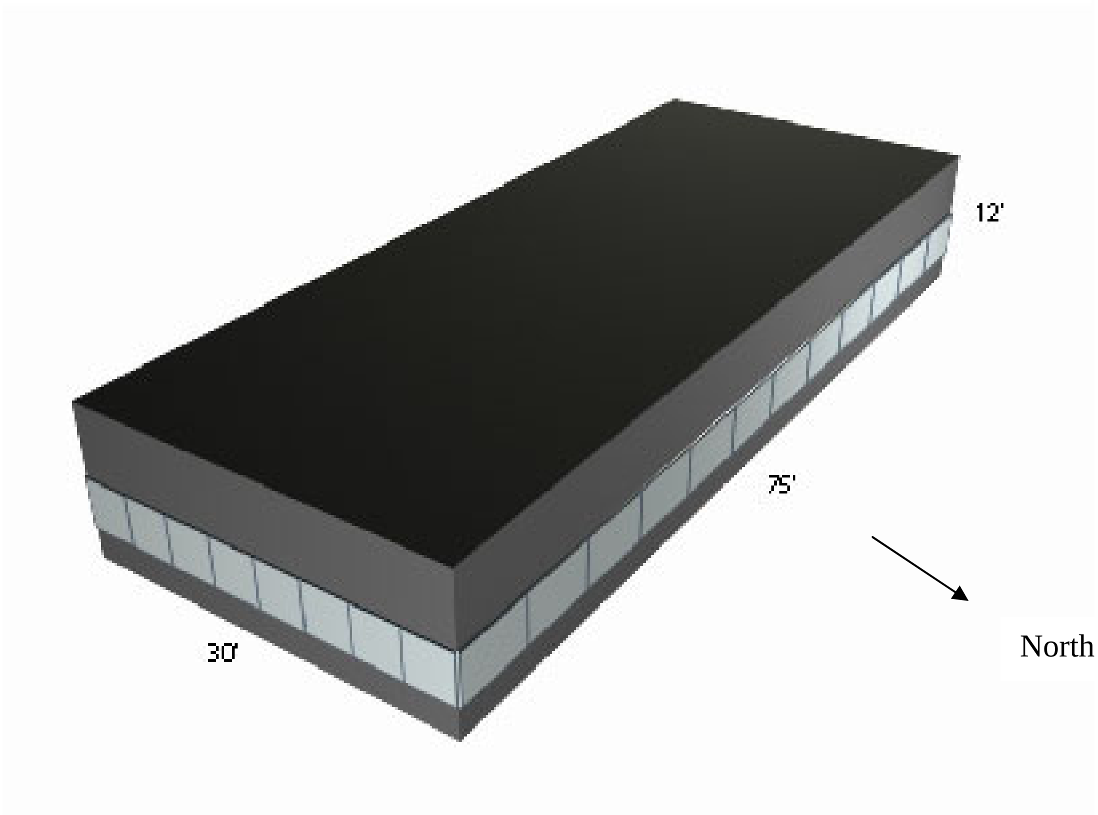
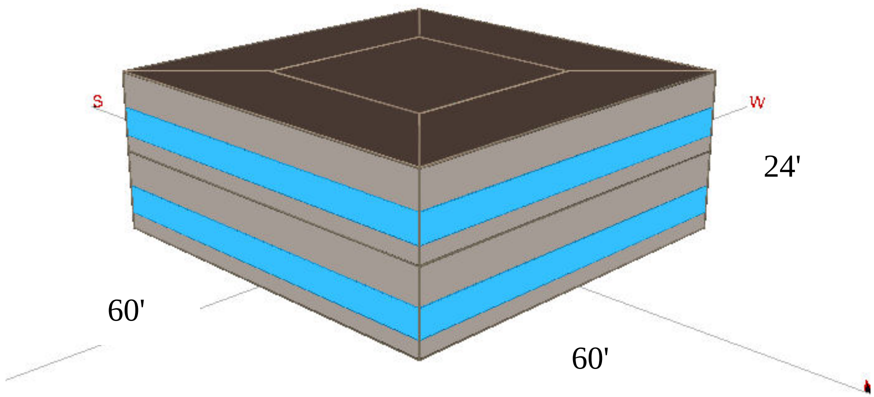
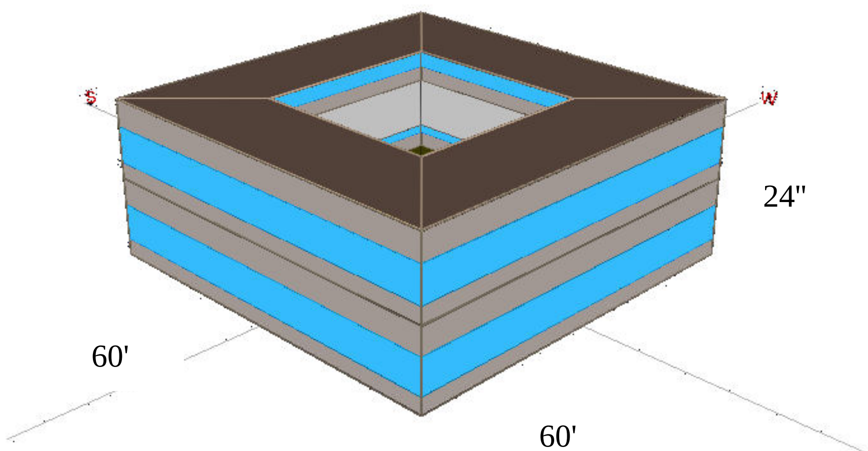


Figure N5-1 – Prototype A



10 zone Prototype B



8 zone Prototype B

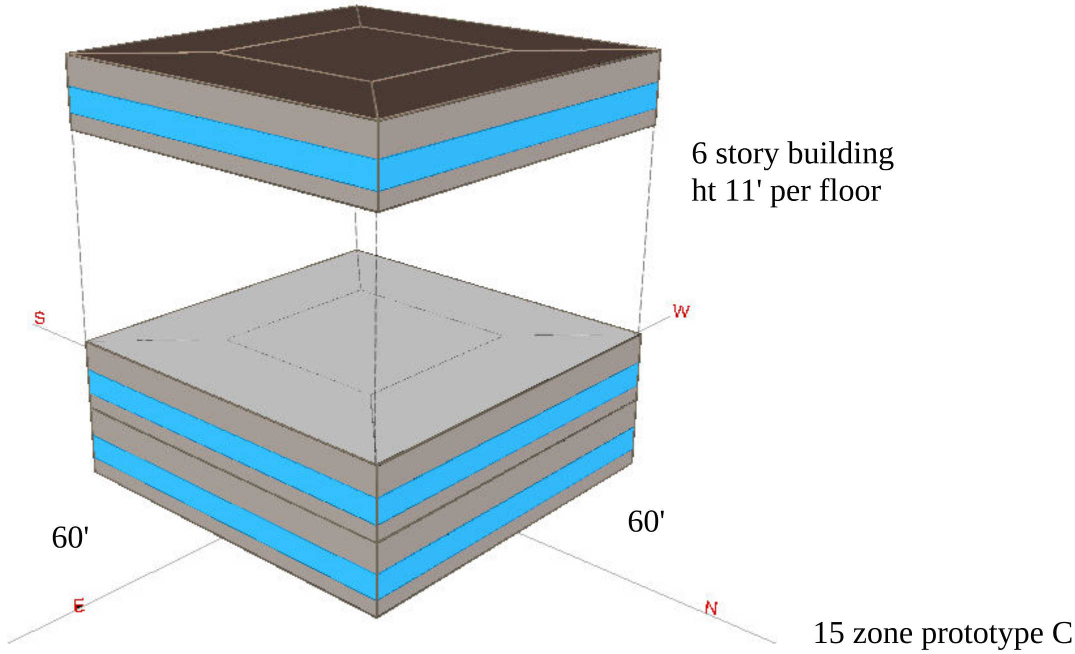


Figure N5-2 – Prototype B and C

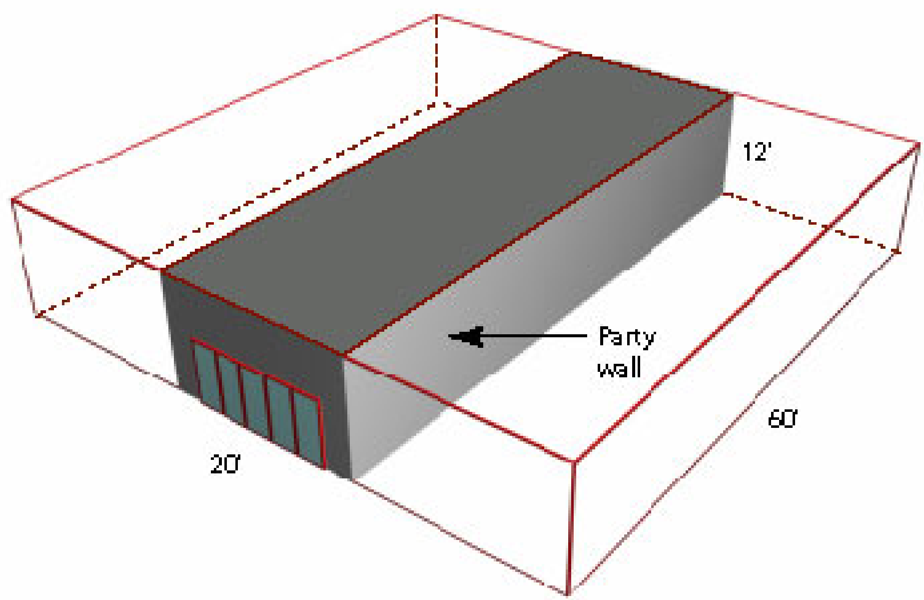


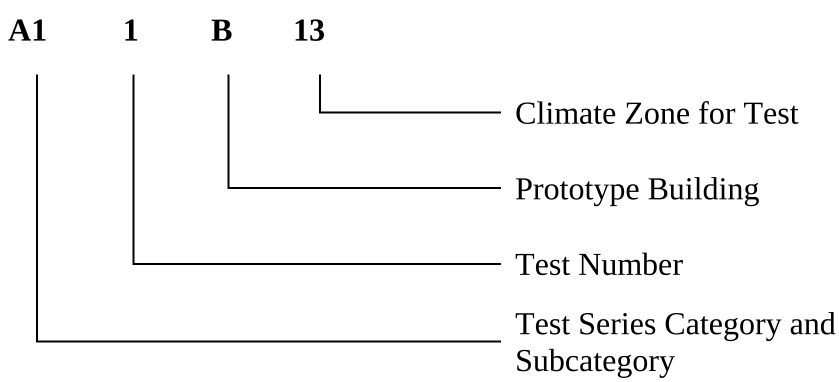
Figure N5-3 – Prototype D

Climate Zones
Eleven of the 16 climate zones are used in the tests. These were chosen to represent distinctly different climate types.

Table N5-1 – Climate Zones Tested

Climate Zone	Example Cities
1	Arcata, Eureka
3	Oakland, San Francisco
7	San Diego
9	Pomona, UCLA
10	Riverside
11	Red Bluff, Redding
12	Sacramento, Davis,
13	Fresno, Visalia
14	China Lake
15	El Centro, Palm Springs
16	Mount Shasta, Tahoe City

Labeling Computer Runs
Each computer run used for the certification tests is given a precise designation to make it easier to keep track of the runs and to facilitate analysis. The following scheme is used:



Test Criteria
Software vendors shall perform a series of computer runs that systematically vary the building prototypes described in Section 5.1.1. These tests consist of a series of matched pairs of computer runs. Each matched pair consists of a proposed design (prototype variation) and the standard design equivalent to the proposed design. The standard design equivalent is the proposed design automatically reconfigured by the ACM according to the rules presented in Chapter 2.
The variations or computer runs are described in Sections 5.2 and 5.3. The computer runs shall all be performed using the modeling assumptions described in this document. For each computer run, the results from the candidate ACM shall be within an acceptable range as defined in this section. The results of these runs shall be compared to the results of a custom budget for the standard building developed by the same program. The applicant shall calculate the following.

$$DT_a = PT_a - ST_a$$

and the Commission has already determined:

$$DT_r = PT_r - ST_r$$

Where:

Subscript "a" represents the results of the applicants ACM and subscript "r" represents the results of the reference program, and

PT is the TDV energy for the proposed budget calculated for the building in kBtu/ft^2-yr,

ST is the TDV energy for the standard budget in kBtu/ft^2-yr.

For all tests, DT_a shall be greater than $0.85 \times DT_r - 1$ kBtu/ft^2-yr when $DT_r \geq 0$ and DT_a shall be greater than $(1.15 \times DT_r - 1)$ when $DT_r < 0$ to be accepted for compliance use. If any of the tests fail to meet these criteria then the ACM will not accepted for compliance use.

For lighting and receptacle loads tests, the TDV energy use of the candidate ACM shall be within 2.0% of the reference method.

The reference method does not allow for undersized systems to be simulated for compliance purposes. **ACMs shall also model adequately sized HVAC systems.** Compliance runs that result in undersized equipment or equipment that cannot meet the heating or cooling loads for a significant fraction of the simulated run shall not be approved for compliance purposes. **For ACMs that report the hours that loads are not met or the hours outside of throttling range, reports shall indicate that these hours are less than 10% of the hours of a year for each and every test in order for an ACM to qualify for approval.**

The vender shall summarize the results on the forms provided in Appendix NA. As previously described, the vendor applicant may challenge the reference program results by providing alternative reference program runs and adequate documentation justifying different reference program results from those given in the Appendix NA.

General Requirements

An ACM shall automatically perform a variety of functions including those described in Chapter 2.

- The ACM shall accept a specified range of inputs for the proposed design, and then use these inputs to describe the proposed building on the required output forms. The proposed building inputs are also used to create a standard design building based on the proposed building and the energy budget generation rules used to incorporate the prescriptive requirements into the proposed design. Certain building descriptors remain the same for both the proposed and standard design but others will change in ways that depend upon the design characteristics, the climate zone, and the prescriptive and mandatory requirements of the standards.

- The ACM shall automatically define the standard design; determine the proper capacity of the HVAC equipment for the standard design; adjust the HVAC capacity of the standard design in accordance with the reference method; and automatically run the standard design to establish the energy budget.

- The ACM shall perform the energy budget run in sequence with the compliance run with no user intervention or input beyond that of the proposed design. The results are reported in Part 2 of the Performance Certificate of Compliance Form (PERF-1) when the proposed building design complies.

The applicant shall perform the tests listed in this Manual to assure that the ACM produces results in general agreement with the reference method. These tests verify the implementation of the custom budget procedure, program accuracy and performance relative to the reference program, and acceptable use of calculation inputs.

The vendor/applicant shall submit the completed forms from Appendix NA and backup documentation for the results of the tests described herein. For buildings that DO NOT COMPLY, the vendor shall supply diagnostic output that indicates noncompliance and gives the TDV energy information needed to evaluate the test criteria, including the lighting and receptacle portions of the energy budgets for both proposed and standard design. For building designs that do comply, the vendor/applicant shall submit copies the Certificate of Compliance generated by the ACM.

For some of the tests, specific occupancy mixes are used and these are designated by the primary occupancy. The distribution of occupancy areas of these mixes are given in the table below. These mixes were selected to result in lighting energy densities nearly the same as those for the occupancy assumptions for spaces/areas without lighting plans.

Table N5-2 – Occupancy Mixes for Tests

Primary Occupancy	Suboccupancy Percentages			
Mix Type	*Primary*	*Office*	*Corridor/Support*	*Storage*
Office	87.5%	87.5%	12.5%	
Retail	85.0%	3.5%	3.5%	8.0%
Clinic	85.0%		15.0%	
Storage	72.0%	18.0%	10.0%	
Grocery	82.0%	4.0%	6.0%	8.0%
Theater	70.0%	16.0%	4.0%	Lobby 10.0%
Restaurant	Dining Area 75.0%	Kitchen 15.0%	5.0%	*Storage* 5.0%
Other	*Other*100.0% (Receptacle Load at 1.0 W/ft^2)			

Partial Compliance Tests - A1 Series (3 tests)

The partial compliance tests use the single zone version of the A building prototype with the same features used (except as noted) in test C11A10 in Section 5.2.4.1.

Test A11A09: Building prototype A - climate zone 09 - Pomona

Partial compliance - envelope only.

NOT A VALID TEST – Test A13A09: Building prototype A - climate zone 09 - Pomona

Partial compliance - envelope and mechanical only. No lighting plans submitted for grocery occupancy.

Exterior Opaque Envelope Tests

The exterior wall tests help to evaluate whether the applicant ACM inserts the correct wall assemblies into the standard design as a function of the proposed design including wall frame type, heat capacity, occupancy type and climate zone. These tests use the eight (8) zone B building prototype without interior zones to increase the tests sensitivities to envelope energy impacts.

The default characteristics for these tests are:

- Prototype building B (geometry, zones, and walls)
- Office occupancy with no lighting plans – lighting wattage at 1.50 watts per square foot

- Envelope
  - Slab-on-grade floor = IV26-A1
  - Roof = IV2-A5.
  - Walls = Varies
  - Window-wall-ratio = 0.10 for opaque-envelope tests [WWR = 0.10]
  - Glazing performance equal to prescriptive requirements
- Package single zone system (gas furnace) without economizers or package variable air volume system with economizer cycle [Standard DOE 2.1E Economizer] and fixed temperature integrated 75 degree Fahrenheit economizer limit temperature - [ECONO-LIMIT-T = 75.0]

Opaque Exterior Envelope - A2 Series (7 tests)

These tests use the default B prototype building geometry and zone configuration. Run tests using wall assemblies IV9-A2, IV11-A2, IV13-D5+IV19-A1, and IV13-B2+IV19-F7 for north, east, south and west walls respectively and roof assembly IV3-A5. The framing percentage used for wood frame walls, e.g., wall type IV9-A2, is 25% . For Tests A21 and A25 use package single zone [PSZ] HVAC equipment in climate zones 13 and 03 respectively. For tests A22, A23, A24 use a package variable air volume [PVAV] system in climate zones 13, 06, and 16 respectively. Test again (A26 and A27) using wall assemblies IV9-A3, IV11-B4, IV13-D5+IV19-F7, and IV13-B2+IV19-D7 for north, east, south and west walls respectively and roof assembly IV3-H5. For test A26 use a package single zone [PSZ] HVAC system in climate zone 13 and for test A27 use a package variable air volume [PVAV] system in climate zone 16.

Table N5-3 – A2 Test Series Summary

Test Run	HVAC System	North Wall	East Wall	South Wall	West Wall	Roof
A21B13	PSZ	IV9-A2	IV11-A2	IV13-D5+IV19-A1	IV13-B2+IV19-F7	IV2-A5
A22B13	PVAV	IV9-A2	IV11-A2	IV13-D5+IV19-A1	IV13-B2+IV19-F7	IV2-A5
A23B06	PVAV	IV9-A2	IV11-A2	IV13-D5+IV19-A1	IV13-B2+IV19-F7	IV2-A5
A24B16	PVAV	IV9-A2	IV11-A2	IV13-D5+IV19-A1	IV13-B2+IV19-F7	IV2-A5
A25B03	PSZ	IV9-A2	IV11-A2	IV13-D5+IV19-A1	IV13-B2+IV19-F7	IV2-A5
A26B13	PSZ	IV9-A3	IV11-B4	IV13-D5+IV19-F7	IV13-B2+IV19-D7	IV2-H5
A27B16	PVAV	IV9-A3	IV11-B4	IV13-D5+IV19-F7	IV13-B2+IV19-D7	IV2-H5

Envelope Glazing Tests

The envelope glazing tests are to check whether the ACM applicant inserts the correct vertical glazing types and areas into the standard design as a function of proposed design glazing orientation, area, occupancy and display perimeter length. As for the opaque envelope tests, the

eight (8) zone B prototype building is used to enhance the sensitivity of the tests for envelope measures.
The prototypes for these tests have the following characteristics:

- Prototype building B, and if not otherwise specified.
- Retail store occupancy :1.70 watts per square foot.
    - Envelope:
        - Wall assemblies: North = IV9-A2, East = IV11-A2, South = IV13-D5+IV19-A1, and West = IV13-B2+IV19-F7
        - Roof = IV2-A5
        - Window wall ratio default of 0.35 [WWR=0.35]
        - Slab-on-grade floor = IV26-A1
        - See test for Glazing Specifications
- Package variable air volume HVAC System

Tests B31 and B32 use prototype building D to test skylight and display perimeter custom budget generation and to simultaneously test ACM overhang modeling.
The prototype has the following characteristics:

- Prototype building D
- Retail (85%) and storage (15%) occupancies hence lighting at 1.70 watts per square foot for the retail and 0.6 watts per square foot for the commercial storage portion at the back.
- 3.5 inch concrete slab-on-grade floor [U-F CONS= IV26-A1]
- At zero building azimuth the long axis of the building zones run due north to south.
- All "exterior" vertical walls of the two unconditioned zones are 2x4 steel-framed walls with framing 16" o.c. and R-11 insulation between framing members. These walls have stucco and plywood on the exterior and sheetrock on the interior [CONS = IV11-A2].
- The vertical walls between the conditioned zone and the two unconditioned zones are 2x4 steel-framed walls with framing 16" o.c. and R-13 insulation between framing members. These walls have sheetrock on both sides [CONS = IV11-A3].
- The northern exterior vertical wall (with glass front) of the conditioned zone is a steel-framed IV11-A2 [METAL-WALL] wall and the southern wall is a massive [HEAVY-WALL] IV13-D5+IV19-A1 wall.
- Wood framed roof - framing materials and layers type IV2-A5
- For the B31 and B32 test runs the window wall ratio is .50 for both exterior walls of the conditioned space [WWR = 0.50]. These windows start on the ground.
- The B31 and B32 test runs both include double pane skylights.
- Clear single pane glass for all glass with 9% aluminum framing with thermal break, SHGC=0.82 G-C=1.62.

- Package single zone system with economizer cycle and compressor lockout (fixed temperature non-integrated economizer [ECONO-LIMIT-T = 75]

Vary Window Wall Ratio - B1 Series (5 tests)
These tests exercise the automatic determination of standard design window wall ratios. These tests are performed using building B. The first three (B11, B12, and B13) are modeled in climate zone 13 and the last two in climate zones 06 and 16 respectively. Wall types IV11-A2, IV9-A2, IV13-B2+IV19-F7, and IV13-D5+IV19-A1 are used as in test series A2. All glazing performance characteristics shall be consistent with the prescriptive standards and no overhangs or side fins will be simulated. The glass will be a continuous band of uniform height around the entire building. Window wall ratios are set at 0.35, 0.40, and 0.45 respectively. The building with a WWR of 0.45 are also simulated in climate zones 06 and 16 for tests B14 and B15. When the window wall ratio is tested at 0.45 [WWR = 0.45] the proposed building is tested with clear low emissivity dual pane glass with 9% aluminum framing with thermal break, SHGC=0.58, G-C=0.68.

- B11B13 – B13B13 HVAC System (See Appendix NF-35)
    - ACLP040L (See Appendix NF-7)
        - Heating: Capacity = 420,000 BTU/h, AFUE = 80
        - Cooling Capacity = 467,000 BTU/h, EER = 8.50
        - CFM = 14,000, BHP = 2.12
        - Economizer = fixed temperature integrated 75 degree Fahrenheit limit temperature [ECONO-LIMIT-T = 75.0]
- B14B06, B15B16 HVAC System (See Appendix NF-35)
    - ACLP040H (See Appendix NF-7)
        - Heating: Capacity = 480,000 BTU/h, AFUE = 84
        - Cooling Capacity = 476,000 BTU/h, EER = 9.00
        -

Tests: B11B13, B12B13, B13B13, B14B06, and B15B16.

Vary Glazing Types With An Overhang - B2 Series (4 tests)
These tests examine the ACM's sensitivity to the energy tradeoffs between extra glazing and overhangs. The first three tests are performed using building B in climate zone 12 with the building rotated 15 degrees to the east in azimuth. The last test is performed in climate zone 03. A retail occupancy is modeled. Overhangs, six ft deep [OH-D=6], 60 ft wide [OH-W=60], and 0.1 ft above the top of the glass [OH-B=0.1] and no extension [OH-A=0] are modeled on the windows. However, no side fins or other building shading will be simulated. The glass will consist of two continuous bands with their bottom edges 2.5 ft from the floor and a height equivalent to a window wall ratio of 0.42 [WWR =0.42] around the entire building. The first three runs will use the three different glass types indicated below for windows on all walls including the north wall. Clear low emissive dual pane glass [9% aluminum framing with thermal break, SHGC=0.58, G-C=0.68] will also be simulated in climate zone 03.
Glass descriptions

1. CLR = GLASS-TYPE S-C=.95 PANES=1 G-C=1.62
2. RFL45 = GLASS-TYPE S-C=.45 PANES=1 G-C=1.62
3. CLRLOWE =GLASS-TYPE   S-C=.66   PANES=2   G-C=0.68

Tests: B21B12, B22B12, B23B12, and B24B03

Display Perimeter & Skylight Tests - B3 Series (2 tests)
These tests examine the ACM's sensitivity to variations in both display perimeter and skylights. These tests are performed using prototype D in climate zone 12. A 4-ft deep, [OH-D=4], 20 ft wide [OH-W=20] overhang, 2 ft above the window [OH-B=2] with no extension [OH-A=0] will be modeled. The building will be rotated 165 degrees clockwise or to the east [BUILDING LOCATION AZ = 165] facing the glazed wall 15 degrees to the east of due South. No side fins or other building shading will be simulated. The glass will be a 6-ft high panel of clear single pane glass [9% aluminum framing with thermal break, SHGC=0.82, G-C=1.62] on both exterior end walls with its bottom edge at floor height. The display perimeter option will be selected with a display perimeter of 40 ft for the D prototype building. [WWR = 0.500 for six foot high glass.] Test B31 will have 5% of the roof area in double pane transparent skylights [9% aluminum framing with thermal break, SHGC=0.44, G-C=1.02] and test B32 will have 10% of the roof area in double pane translucent skylights [9% aluminum framing with thermal break, SHGC=0.70, G-C=1.02].
Tests: B31D12 and B32D12

Occupancy Tests
The occupancy tests check to see if the ACM applicant inserts the correct schedules, envelope performance requirements, fixed values for internal loads and ventilation rates as a function of the occupancy type. Window wall ratio has been lowered to 0.20 for building prototype A and 0.30 in prototype B to increase the sensitivity of the tests to the choice of occupancy.
The prototypes for these tests all have the following characteristics:

- Prototype building A
- Specified occupancy mixes except lighting at 0.05 watts per square foot higher than allowed by Table N2-2 with lighting plans submitted.
- Wood framed roof - framing materials and layers type IV2-A2
- Suspended wood floor - framing materials and layers per Joint Appendix IV, floor type IV21-A1
- Package single zone system with economizer, fixed temperature integrated 75 degree Fahrenheit limit temperature
- [ECONO-LIMIT-T = 75.0]
- Window wall ratio = 0.20
- Glazing meets prescriptive standards for CZ13

Tests will also be run for a mixed office, retail, restaurant, and heated-only warehouse occupancies for prototype building B and a second mixed occupancy test will be done using prototype C as a "prototype" high-rise hotel.

- Prototype buildings B (ten zone version)
- Modeled occupancy mixes except lighting at 0.02 watts per square foot lower than allowed by Table N2-2 with lighting plans submitted.
- 3.5 inch concrete slab-on-grade floor [U-F CONS=IV26-A1]
- Wood framed roof - framing materials and layers type RF1C
- Two (Interior Zones and Perimeter Zones) Packaged Variable Air Volume Systems with Electric Reheat and Economizer fixed temperature integrated 75 degree Fahrenheit economizer limit temperature for Prototype B. [ECONO-LIMIT-T = 75.0]
- Window wall ratio = 0.35 [WWR = 0.35]
- Glazing performance equal to prescriptive requirements

Prototype building C is described in detail below by the reference program input files. The mixed-occupancy high-rise hotel has a hotel lobby, office, and three retail zones on the first floor; hotel guest rooms on the middle floors; and three hotel function area zones, a kitchen, and dining zone on the top floor. In addition to the primary occupancy, each perimeter HVAC zone has 12% of its area as corridor, restroom, and support occupancy. The interior or core HVAC zones have 20% of their area as corridor, restroom, and support occupancy to account for elevators and electrical and mechanical chases.

- Prototype building C
- Lighting is set to the prescriptive requirement for each occupancy task/area per Table N2-2.
- Concrete spandrel panel walls IV15-D4
- Raised concrete floor IV25-A4
- Roof IV2-A5 Variable air volume system with hot water reheat and fixed temperature integrated economizer cycle and 75 degree Fahrenheit economizer limit temperature serving non-hotel room occupancies
  [ECONO-LIMIT-T = 75.0]
- Four pipe fan coil system serving all hotel rooms
- Window wall ratio = 0.35 [WWR = 0.35]
- Glazing performance equal to prescriptive requirements for climate zone 13. Double pane clear windows [9% aluminum framing with thermal break, SHGC=0.77, G-C=0.838] are used for north-facing glazing and non-north-facing guestroom glazing. Double pane bronze windows [9% aluminum framing with thermal break, SHGC=0.50, G-C=0.838] are used for non-north-facing glazing for all other occupancies.

Single Occupancy Tests - C1 Series (5 tests)

These tests will be performed using the Building A in climate zone 10 for the 5 occupancy mixes listed below. Sub-occupancy assumptions are given in Table N2-3 of this manual:

C11A10	Grocery	82% Grocery Sales	8% Storage	6% Support	4% Office
C12A10	Restaurant	65% Dining Area	30% Kitchen	5% Support	
C13A10	Theater	70% Theater (Perf)	20% Lobby	5% Support	5% Office
C14A10	Clinic	50% Medical-Clinic	25% Office	25% Support	
C15A10	All "Other"	100% Other			

Tests: C11A10, C12A10, C13A10, C14A10, and C15A10

Mixed Occupancy Tests - C2 Series (2 tests)

a) This test will be performed using the ten zone version of Prototype Building B in climate zone 10 with the first story north and south zones retail, first story east and west zones heated-only warehouses and the first floor interior zone and all second story zones are office occupancies.
Packaged single zone [PSZ] gas/electric HVAC systems are modeled in the heated-only warehouse zones in lieu of the packaged variable air volume [PVAV] system.

b) This test will be performed using the Prototype Building C in climate zone 16 with the first story having retail occupancies in all zones except for the west zone which is a hotel lobby and the south zone which is an office, four middle stories of hotel guest rooms with five zones per floor, and a top floor with hotel function zones for the north, east, and west zones, a kitchen for the interior zone and dining occupancy in the south zone.
Tests: C21B10 and C22C16

Lighting Tests - D1 Series (4 tests)

The lighting tests check whether the ACM applicant inserts the correct lighting levels, per zone, into the standard design.
The prototype has the following characteristics:

- Prototype building D
- Retail area occupancy with lighting plans
- 3.5 inch concrete slab-on-grade floor [U-F CONS=IV26-A1]
- Wood framed roof - framing materials and layers type IV2-A5
- Window wall ratio of 0.30 [WWR = 0.30]
- Clear single pane glass for all glass with 9% aluminum framing with thermal break, SHGC=0.82, G-C=1.62.
- Package single zone system with economizer cycle and compressor lockout (non-integrated economizer [ECONO-LIMIT-T = 75]

These tests are performed using building D in climate zones 12 (Sacramento) and 07 (San Diego) with two different lighting levels, 1.50 watts per square foot and 1.70 watts per square foot.
Tests: D11D12, D12D12, D13D07, and D14D07

Ventilation Tests - E1 Series (6 tests)

The ventilation tests check whether the ACM applicant inserts the correct tailored ventilation rates, per zone, into the standard design. These tests are performed using Building D in climate

zone 16 with three different combinations of tailored ventilation rates. Repeat these tests in climate zone 14.
The prototype has the following characteristics:

- One zone industrial and commercial storage occupancy with lighting plans showing 0.8 watts per square foot of lighting
- 3.5 inch slab on grade floor IV26-A1
- Wood framed roof - framing materials and layers [Roof Type IV2-A5]
- Window wall ratio of 0.10
- Clear double pane glazing on exterior walls with 9% aluminum framing with thermal break, SHGC=0.77, G-C=0.838.
- Package single zone system with no economizer

First, standard outside air per person [OA-CFM/PER] rates are used based on occupancy assumptions in Table N2-2 or N2-3. Next outside air per person [OA-CFM/PER] rates are increased by a factor of 1.5 as a tailored ventilation entry. Finally, outside air per person [OA-CFM/PER] rates are increased by a factor of three as a tailored ventilation entry.
Tests: E11D16, E12D16, E13D16, E14D14, E15D14, and E16D14

Process Loads Tests - E2 Series (6 tests)

The process loads tests check the energy budget effects of zonal process (tailored) equipment levels and microclimate sizing in a proposed building design. These tests are performed using prototype building B with conditioned interior zones in climate zone 16 (Tahoe City) with three different extra process loads of 0.50, 1.00, and 2.00 watts per square foot of process heat scheduled as equipment. Repeat these tests in climate zone 12 (Davis).
The prototype has the following characteristics:

- Prototype building B including 30'x30' interior zones
- Office occupancy
- 3.5 inch concrete slab-on-grade floor [U-F CONS=IV26-A1]
- Wood framed roof - framing materials and layers type IV2-A5
- Package variable air volume system with integrated economizer
- Window wall ratio = 0.30 [WWR = 0.30]
- Single pane reflective glass with solar heat gain coefficient of 0.40 [9% aluminum framing with thermal break, G-C=1.62] everywhere.
- Lighting wattage at 1.20 watts per square foot

Tests: E21B16, E22B16, E23B16, E24B12, E25B12, and E26B12

HVAC System Tests - F1 Series (5 tests)

The HVAC system tests check the ACM's sensitivity to variations in HVAC system type and the selection of comparative systems for the standard design as a function of specific city location within climate zone, occupancy, square footage and proposed HVAC system type. Test F15A01 is a heated-only warehouse with electric resistance heating. The systems to be used for establishing custom budgets, are described in Chapter 2.

Tests 1 and 2 (F11A07 & F12A13):

- Prototype building A
- Medical office/clinic occupancy
- Window wall ratio of 40% [WWR = 0.40]
- Heat Pump System
- F11A07 modeled in climate zone 07 (San Diego)
- F12A13 modeled in climate zone 13 (Visalia)

Tests 3 and 4 (F13B12 & F14B12):

- Prototype building B - 8 zone version
- Retail occupancy
- Window wall ratio of 35% [WWR = 0.35]
- PVAV with electric reheat and no hot water coils or boilers
- F13B12 modeled in climate zone 12 (Sacramento)
- F14B12 modeled in climate zone 12 (Crockett)

Test 5: (F15A01)

- Prototype building A
- Heated only warehouse occupancy - gas-fired unit heater
- Modeled with clear, double pane, low emissivity glass, 9% aluminum framing with thermal break, SHGC=0.58, G-C=0.68
- Window wall ratio of 35% [WWR = 0.35]
- Electric resistance heating - No cooling installed
- F15A01 modeled in climate zone 01 (Eureka)

Table N5-4 – F1 Test Series Summary

Test Run	HVAC System	Location	WWR	Occupancy
F11A07	Heat Pump	San Diego	0.40	Medical
F12A13	Heat Pump	Visalia	0.40	Medical
F13B12	PVAV with electric reheat	Sacramento	0.35	Retail
F14B12	PVAV with electric reheat	Crockett	0.35	Retail
F15A01	Electric resis. heating only	Eureka	0.35	Warehouse

System Sizing Tests - G1 Series (6 tests)

The system sizing tests check whether the ACM applicant calculates and simulates the correct capacities for both the proposed and standard design systems as a function of the input HVAC system capacities.

These tests are divided among undersized systems, oversized systems and combinations of oversized and undersized system components (e.g. oversized cooling and undersized zone reheating capacities). For the purposes of these tests OVERSIZED means 100 percent over estimated load and UNDERSIZED means 50 percent of the estimated load.

The system sizing tests will be performed in climate zones 3, 11, and 16. Tests 1,2,3 & 4 will be performed using building prototype A in climate zone 11 and tests 5 and 6 using the ten zone building prototype B in climate zones 03 and 16 respectively. Tests 5 and 6 will be performed using the ten HVAC zone version of prototype building B. Systems will be both undersized by 50% (tests 2 & 4) and oversized by 100% (tests 1 & 3.) Tests 5 and 6 have both undersized and oversized systems and components (boilers) serving different zones.

Tests 1 and 2 (G11A11 & G12A11):

- Prototype building A
- Medical office/clinic occupancy
- Window wall ratio of 40% [WWR = 0.40]
- Oversized (G11) and undersized (G12) PSZ - package gas/electric - system (gas furnace and DX cooling)
- Climate zone 11 (Red Bluff).
- No economizer

Tests 3 and 4 (G13A11 & G14A11):

- Prototype building A
- Medical office/clinic occupancy
- Window wall ratio of 40% [WWR = 0.40]
- Oversized (G13) and undersized (G14) heat pump system
- Climate zone 11 (Red Bluff).
- No economizer

Tests 5 and 6 (G15B03 & G16B16):

- Prototype building B - 10 zone version
- Office occupancy
- Window wall ratio of 35% [WWR = 0.35]
- Integrated economizers
- For G15 - oversized boiler, undersized PVAV with electric reheat for exterior zones, oversized PVAV for interior zones
- For G15 climate zone 03 (San Francisco)
- For G16 - undersized boiler, oversized PVAV with electric reheat for exterior zones, undersized PVAV for interior zones
- For G16 - climate zone 16 (Tahoe City)

HVAC Distribution Efficiency Tests

ACM duct efficiency calculations shall be completed based on Appendix NG for the cases shown in Appendix NH.

Optional Capabilities Tests

ACMs may also model other optional capabilities or have optional compliance capabilities for additions and alterations.

The first series of optional tests are special tests to test certain compliance options - partial compliance and modeling of an addition and an existing building with alterations. In addition to the test criteria for the energy results, compliance forms shall conform to the requirements for these special compliance options for the ACM to be approved.

The main body of optional capabilities tests deal with additional HVAC systems and plant capabilities that can be modeled by the DOE 2.1 (especially DOE 2.1E) computer program. These tests and the reference comparison method for these tests conform to the features and rules specified in Chapters 2 and 3 of this manual unless specifically noted otherwise.

OC Test Series - Compliance Options

Test OC1A09: Building prototype A - climate zone 09 - UCLA

Combined compliance for an altered existing building with a non-complying addition. Occupancy is an existing restaurant in a prototype A building. A new solarium is submitted as an addition to the restaurant. The solarium addition is 20 ft deep by 30 ft wide and is 12 ft high adjacent to the wall of the existing building descends to 8 ft at the outer glass wall of the addition. The addition has been added onto the eastern 30 ft wide end of the A prototype building and that eastern wall and its glazing is removed with the construction of the addition. The vertical walls of the addition have 2.5-ft knee walls with the rest of the walls consisting entirely of high performance glass:

- Knee walls - insulated spandrel panels
  SPANDREL-R10 assembly
- Sloped roof - insulated spandrel panels
  SPANDREL-R15 assembly
- Vertical glass walls
  GR4SC26 assembly [dual pane glass, 9% aluminum framing with thermal break, SHGC=0.26, G-C=0.2629]
- Sloped glazing in roof
  GR4SC18 assembly [dual pane glass, 9% aluminum framing with thermal break, SHGC=0.18, G-C=0.2629]

There is NO roof overhang extending beyond the addition's vertical walls. The original restaurant lighting of 2.00 watts per square foot has been altered to 1.60 watts per square foot to compensate for the extra glass in the solarium addition. The 30-ft wide eastern wall is removed to open the existing building to the solarium addition. The remainder of the A building prototype has exactly the same characteristics, including non-lighting occupancy assumptions, used in the proposed building for test C12A10 and is not altered for compliance. To be approved for the capability of partial compliance all ACM output and reporting requirements SHALL be met.

O1 Test Series - Fan Powered VAV Boxes

These tests use the ten zone version of the B building prototype with the same features used (except as noted) in test B11B13. All rules applicable to System #4 (Built-up VAV) described in Section 2.5 Required Systems and Plant Capabilities also apply to fan-powered VAV boxes or power induction units [PIU]. In particular, the rules used to determine a standard HVAC system are the rules for System #4.

Test O11B02: Building prototype B - climate zone 02 - Napa

Central VAV with hot water reheat. Each perimeter zone has a 600 cfm parallel fan powered VAV box. The reference method does not use the [ZONE-FAN-CFM] input, but does set [TERMINAL-TYPE = PARALLEL-PIU], [ZONE-FAN-KW is set greater than or equal to 0.00033], the [ZONE-FAN-T-SCH] is set 1 ^{o}F above heating setpoints, [MIN-CFM-RATIO = 0.3], and ACM input for the [ZONE-FAN-RATIO] or its equivalent is restricted to the range of 0.4 to 1.00. The ACM shall automatically determine or the ACM user shall enter an [INDUCED-AIR-ZONE] which is different than the zone served. For the reference program and method, the [INDUCED-AIR-ZONE] shall be the U-name (user name) of another zone.

Test O12B02: Building prototype B - climate zone 02 - Napa

Central VAV with hot water reheat. Each perimeter zone has a 600 cfm series fan powered VAV Box. The reference method does not use the [ZONE-FAN-CFM] input, but does set [TERMINAL-TYPE = SERIES-PIU], [ZONE-FAN-KW is set greater than or equal to 0.00033], the [ZONE-FAN-T-SCH] is set 1 ^{o}F above heating setpoints, [MIN-CFM-RATIO = 0.3], and ACM input for the [ZONE-FAN-RATIO] or its equivalent is restricted to the range of 0.4 to 1.00. The ACM shall automatically determine or the ACM user shall enter an [INDUCED-AIR-ZONE] which is different than the zone served. For the reference program and method, the [INDUCED-AIR-ZONE] shall be the U-name (user name) of another zone.

O2 Test Series - Supply/Return Fan Options

This series tests various fan options for central VAV system fans. These tests use the ten zone version of the B building prototype with the same features used (except as noted) in test B11B13. All runs have a central VAV HAVC system with a gas-fired boiler to supply hot water reheat.

Test O21B13: Building prototype B - climate zone 13 - Fresno

The supply fan uses an air foil fan with inlet vane control to control fan volume. The fan part-load curve is taken from the Commission's *DOE-2 Compliance Supplement*.

Test O22B13: Building prototype B - climate zone 13 - Fresno

The supply fan uses an air foil fan with discharge damper control to control fan volume. The fan part-load curve is taken from the Commission's *DOE-2 Compliance Supplement*.

Test O23B13: Building prototype B - climate zone 13 - Fresno

The supply fan uses an forward curve fan with inlet vane control to control fan volume. The fan part-load curve is taken from the Commission's *DOE-2 Compliance Supplement*.

Test O24B13: Building prototype B - climate zone 13 - Fresno

The supply fan uses a vane axial fan control to control fan volume. The fan part-load curve is taken from the Commission's *DOE-2 Compliance Supplement*.

O3 Test Series - Special Economizer Options

This series tests various economizer options. These tests use the A building prototype with the same features used (except as noted) in Test C11A10. All runs have a packaged single zone

HVAC system with a gas-fired furnace and electric DX cooling. The building uses a grocery occupancy mix contained within a single (one thermostat) HVAC zone.
Proposed plans specify the sub-occupancies within the single HVAC zone with lighting watts per square foot:

Subzone Space Occupancy	Percentage of Area	Proposed Lighting
Grocery Sales Area	82%	1.50
Grocery Storage (Commercial Storage)	8%	0.80
Support/Corridors	6%	0.80
Office	4%	1.80

Test O31A12: Building prototype A - climate zone 12 - Fairfield
The HVAC system is equipped a fixed enthalpy integrated economizer control for more efficient cooling. The DOE 2.1E economizer function is used with [OA-CONTROL = TEMP], [ECONO-LIMIT-T = 75], [ENTHALPY-LIMIT = 25.0 Btu/lb], and [ECONO-LOCKOUT = YES].
Test O32A12: Building prototype A - climate zone 12 - Fairfield
The HVAC system is equipped a fixed enthalpy non-integrated economizer control for more efficient cooling. The DOE 2.1E economizer function is used with [ENTHALPY-LIMIT = 25.0 Btu/lb] and [ECONO-LOCKOUT = NO].
Test O33A12: Building prototype A - climate zone 12 - Fairfield
The HVAC system is equipped a differential enthalpy integrated economizer control for more efficient cooling. The DOE 2.1E economizer function is used with [OA-CONTROL = ENTHALPY].

O4 Test Series - Special HVAC Control Option

Test O41B13: Building prototype B - climate zone 13 - Fresno
This test exercises a warmest zone cooling coil control option. This test uses the ten (10) zone version of building prototype B with the same features used (except as noted) in test B11B13.

O6 Test Series - Additional Chiller Options

This series tests various chiller options. These tests use the ten (10) zone B building prototype with the same features used (except as noted) in test F14B13. All runs have a central HVAC system with one of the new chiller options and a gas-fired boiler and use hot water reheat.
Test O61B12: Building prototype B - climate zone 12 - Placerville
The chiller for this test is a single stage absorption chiller modeled with an EIR = 0.004 and an HIR = 1.6.
Test O62B12: Building prototype B - climate zone 12 - Placerville
The chiller for this test is a two stage absorption chiller modeled with an EIR = 0.004 and an HIR = 1.0.
Test O63B12: Building prototype B - climate zone 12 - Placerville
The chiller for this test is a gas-fired absorption chiller modeled with an EIR = 0.0114 and an HIR = 1.0.
Test O64B12: Building prototype B - climate zone 12 - Placerville
The chiller for this test is a variable speed drive (VSD) chiller modeled with an EIR = 0.2275.
Test O65B12: Building prototype B - climate zone 12 - Placerville
The chiller for this test is a screw chiller modeled with an EIR = 0.2275.

Test O66B12: Building prototype B - climate zone 12 - Fairfield
The chiller for this test is also a screw chiller modeled with an EIR = 0.2275 in a different city in climate zone 12.

O7 Test Series - Additional HVAC System Options

This series tests various additional HVAC system options. These tests use the ten (10) zone B building prototype with the same features used (except as noted) in test F13B12. All runs have a central HVAC system with the same chiller as that used in test F13B12 and (where needed) a gas-fired boiler for hot water reheat.
Test O71B12: Building prototype B - climate zone 12 - Sacramento
Individual hydronic heat pumps (< 75K Btuh) are modeled for each zone. The heat pumps all have EER = 11.0 and COP = 3.8.5.3.8 O8 Test Series - Optional Shading Devices.
This test series tests the effects of optional shading devices, in particular sidefins. In this series sidefins are tested in two hot climate zones at both ends of the state to maximize differences in latitude and thus solar angles. The building is the same as that used in Test C11A10 except as noted below.
The occupancies and lighting are the same as that specified for **Test** O1A09and the **O3 Test Series**.
Test O81A11: Building prototype A - climate zone 11 - Red Bluff
The glazing is the same as in Test C11A10 except that there are 2-ft deep sidefins every 5 ft that are the same height as the windows.
Test O82A15: Building prototype A - climate zone 15 - Palm Springs
This test is the same as Test O81A11 except that the test is modeled in climate zone 15 - Palm Springs.

O9 Test Series - Evaporative Cooling Options

This test series tests direct, indirect, and direct/indirect evaporative cooling systems.
Evaporative cooling is used both alone or as a precooling system. The building is the same as that used in Test C11A10 except as noted below. The occupancy type is the grocery with 12% storage space; and lighting (with lighting plans) is set at 1.65 watts per square foot for all spaces modeled.
Standard Design Assumptions. The standard HVAC system for evaporative cooling is a DOE 2.1E gas/electric packaged single zone unit [DOE 2.1E PSZ] with a fan power index 0.196 watts per cfm less than the proposed system which has additional fan capacity to move high air volumes required for evaporative cooling. The DOE 2.1E reference program characteristics for the standard system include [SUPPLY-DELTA-T = 1.815] and [SUPPLY-KW = 0.000587].
Proposed Design Assumptions. The proposed HVAC system for these O9 series tests will include the evaporative cooling system plus a backup DOE 2.1E packaged single zone [PSZ] with [SUPPLY-DELTA-T = 2.42] to account for additional heating of the air stream by additional and/or larger fans, [SUPPLY-KW = 0.000783] to account for the evaporative cooling fan. **ACMs may allow user entry of supplementary fan and pump power but they shall have a minimum supplementary power use (similar to the fan power index) of 0.5 watts per cfm to account for supplementary fans and pumps [EVAP-CL-KW not less than 0.0005 (DOE 2.1 Default)].** The entry for [EVAP-CL-KW] for DOE 2.1E is given:

Equation N5-1 $$\left[EVAP - CL - KW\right] = 0.746 \times \frac{(EF_{sp} + EP_{sp})}{0.85}$$

where

EF_{sp}	is the nameplate horsepower of the evaporative supplementary fan(s)
EP_{sp}	is the nameplate horsepower of the evaporative supplementary pump(s)
0.85	is a power factor to convert nameplate horsepower to brakehorsepower

For the proposed design, an ACM shall limit direct and indirect evaporative cooling effectiveness to the DOE 2.1E defaults as a maximum entry.

Test O91A13: Building prototype A - climate zone 13 - Fresno

A packaged single zone system is modeled with supplemental indirect evaporative cooling. This test is used to verify the proper upsizing of an undersized cooling system, as well as to ensure that the evaporative cooling is not upsized. This test is also used to verify the correct accounting of supplemental energy associated with the evaporative cooling process, and the implementation of the indirect cooling algorithms.

Test O92A11: Building prototype A - climate zone 11 - Redding

A standalone indirect/direct evaporative cooler is modeled with no supplemental air conditioning proposed. This test is used to verify the correct selection of the standard HVAC system and the ability of the ACM to create the proper cooling system which functions with the evaporative cooling system as a supplement to mechanical cooling. This test is also used to verify the correct implementation of the indirect/direct evaporative cooling algorithms.

Test O93A12: Building prototype A - climate zone 12 - Placerville

A standalone indirect/direct evaporative cooler is modeled with no supplemental air conditioning proposed. This test is the same as Test 092A11 except modeled in a different city with a milder cooling climate where the evaporative cooler alone may be sufficient. This test is used to verify the correct selection of the standard HVAC system and the ability of the ACM to determine the need for the proper cooling system which functions with the evaporative cooling system as a supplement to mechanical cooling and create it if needed.

Test O94A13: Building prototype A - climate zone 13 - Fresno

A standalone indirect/direct evaporative cooler is modeled with no supplemental air conditioning proposed. This test is the same as Test O92A11 except modeled in a different city with a milder cooling climate where the evaporative cooler alone may be sufficient. This test is used to verify the correct selection of the standard HVAC system and the ability of the ACM to determine the need for the proper cooling system which functions with the evaporative cooling system as a supplement to mechanical cooling and create it if needed.